Master Thesis

TIDAL POWER:

Understanding Socioeconomic Issues and Opportunities of Marine Technologies and an Emerging Tidal Energy Industry in Dundee Scotland

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Declaration

I hereby establish that I am the one and only author of this thesis and it is a merchandise of my own academic research.

Jatin Pachisia

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Acronyms

TW	Terawatts
TISEC	Tidal In-Stream Energy Conversion
RE	Renewable Energy
R&D	Research and Development
OE	Ocean Energy
MW	Megawatt
FIT	Feed-in Tariff
ComFIT	Community Feed-In Tariff
kWh	Kilowatt hour
IPCC	Intergovernmental Panel on Climate Change
$C0_2$	Carbon Dioxide
OTEC	Ocean Thermal Energy Conversion
MCT	Marine Current Turbines

ABSTRACT

Given the current situation, there is unsettlement over the global climate change, along with that, the cognizance on the worldwide population about the certain need to help reduce the greenhouse gases and in overall the emissions. This has basically led us to help increase the production of energy from renewable resources of energy and lessen our dependence on fossil fuels. The usage of Tidal energy is turning out to be one of the potential energy producers in the 21st century. The potential is massive. Worldwide, the tidal energy that is technically harvestable are along the areas close to the coast and there are several sources where the energy can be obtained up to 1 terawatts (TW) Also, the potential for tidal current technologies is larger than that of tidal range. There are two ways in which the energy can be extracted from the tides that come from the movements of water which can be vertical which takes place with the rise and fall of water, kinetic energy and potential energy, namely, tidal currents. The tidal range technologies help gather the potential energy. On the other hand, the tidal stream turbines help harvest the energy from the tidal currents.

The province of Dundee in Scotland has been quietly getting itself into the front seat to make capital out of the opportunities such a boom will offer. The construction process has been going on since the early 2005 where the beginning of the foundations had begun already. This will help push for renewable energy jobs and get more investments in the city but it was only last year that steps had been taken to formalize with the establishment of the Dundee Renewables. The thesis will explore the issues and opportunities of the tidal in-stream energy conversion (TISEC) industry. The collection of data is made with thorough knowledge and reviewing of the socio-economic issues related to that of TISEC and the other green energy technologies on an international and national scale by emphasizing on regulatory frameworks, research and projects. Further discussions will be made about the projects, case studies and tools that relate to the economic benefits and the development of the community. The particular components of TISEC development will be addressed: 1) The development of the workforce, technology and supply chain; 2) the importance of financing and funding; 3) the welfare that are brought to the community; 4) policies, assessment and the collaborator processes. The TISEC on Dundee will also contain a gap analysis and the current state will be discussed about. There will be several issues discussed related to the legislation and practices to date.

1 Introduction

In the section below, an outline of the thesis topic will be depicted. The frame work, the questions involved with the research, methodology and the constraints.

1.1 Renewables, the other venture for the crisis.

The requirements globally have put our dependence on producing energy from fossil fuels further more than what it has been. The release of $C0_2$ and other harmful gases into the environment has been bringing about a change in the methods for producing energy and people are getting more involved with the renewable sources of energy.

The release of the CO_2 into the atmosphere from the further burning of the fossil fuels has cramped up the Earth from being able to radiate heat received from the sun back into space, which has resulted in a rise in global temperature. Due to this reason, many countries all around the globe have decided to come up with policies and regulations to help protect the only planet where living organisms can exist. The significance for every individual to understand the importance of the need to help reduce the emission of greenhouse gases mostly from the electricity market.

Along with that, there has been an alarming rate of increase in the production of energy from the conventional sources of energy such as coal and nuclear to alleviate the dependence on oil which has brought upon acid rains and the concerned public's reaction over nuclear waste.

In order to circumvent the threatening anthropogenic damage to the climate, the ones making the policies have to enact laws on the reduction of emission strategies. The technologies that will help reduce the emission of carbon into the atmosphere will be condemnatory and help proceed one step further into achieving greenhouse gas concentration to reduce. (Moomaw, 2008).

The only options available on the supplying of energy are nuclear, multiple other renewable energy sources that rely upon the capturing of natural energy such from the sun, the wind, geothermal and hydropower. (Moomaw, 2008).

There have been many concerns over the past decades by the policy makers to help reduce the greenhouse emissions and help shift the generating of power to more natural sources of energy which are sustainable and environmentally amiable. (Charlier, 2006). Sustainability development is at the heart of the agenda of Europe. The need to improve better needs of energy, the social welfare, economic growth and the protection of the environment are the parts of the agenda. (Commission of the European Communities, 2006). There have been many concerns related to this and reports and studies have depicted that if this is not taken seriously, more than 65 % of the total energy consumed in Europe will have to be imported enclosed by 25-30 years. The pressure continues to burden itself on the European countries to harness the energy in a fiercer manner. (Denny, 2009). The European Union has been at the forefront to help deal with the issues of climate change. It is being approximated that more than one trillion euros could be needed over the next 15 years to help tackle with the demands of energy and in the need of infrastructure to help replace the previous ones. The European countries have come up with many protocols such as the Kyoto to help tackle these issues with the other countries. Of that list, around 7 countries have even more to combat than the rest of the average countries (11%) for the goal which they had set for the year 2020, with the United Kingdom topping the list with a 14% and the Ireland behind them with (13%) to fill the void (Europe's Energy Portal, 2010). Europe is surrounded by numerous islands and four seas: The Mediterranean, the Baltic, the North Sea and the Black Sea; and along with that by two oceans: The Arctic ocean and the Atlantic. Hence, it has always been possible for them to have good relationship with the oceans. The oceans have always managed to play an important role in the producing and development of energy. (Commission of the European Communities, 2006). Therefore, in order to recognise the potential of her maritime dimension. Around 5 to 7% of The European (GDP) is determined to be produced by the marine Industries.

1.2 The need for Ocean Energy

When we think of 'Renewable Energy' the first thought that comes to our mind if that of the prominent wind turbines or the solar panels. The continuous decline in the costs for the solar PV and the onshore wind has reached a point where they will eventually be undercutting the cheapest source of energy producing fossil fuels. [3]

The share of renewables in meeting the global energy demands will have increased by one-fifth I the next five years to reach 12.5% by the year 2023. [4]

Renewables remain the fastest growing sector providing almost 30%of the power requirement demands in 2023 from a stooping 23% in the year 2017.

Hydropower is being said to remain as the largest renewable source, matching around 16% of the global electricity requirements by the year 2023, being followed by wind at (6%), solar PV at (4%) and the remaining (3%) is bioenergy.

It is turning into something important to capture the energy from the sun and wind. But there is only one ruination. The solar and wind power are considered to be intermittent sources of energy. This means that they are not readily available at all times. Whereas, the wind comes and goes, the sun mostly shines during the day time. [5]. There are not many places available to extract the wind energy at all times and be able to generate electricity at a constant rate.

But when we talk of the ocean waves, the waves are constantly crashing making them ideal for generating energy as per the demands. Wave energy systems make usage of the movement of the water to generate electricity. There are many types of equipment that could harness the power from these waves. The generated electricity can be used for many purposes. It can be used to be sent to the electric grid where the generated electricity could be used to power homes and buildings. [5].

Oceans cover more than 69% of the earth and have also been considered as a vast source of green energy source. The industry is growing and it definitely has the potential to cover the global demand for electricity. [6]

The research and further development of these technologies would be strongly affected by the coming up policies for energy. Where solar and wind have gained considerable attention, the attention should now be turned towards the energy from oceans.

The sector of ocean has been heading towards the reality of commercialisation invariably. Even though the world has plenty of water around but being able to access it all is not an easy task, nor is the ocean energy market an easy place to do business at. [7] The investments are high which lead to many countries backing out or not being able to have enough capital. The world's ocean and the seas are huge and untapped sources of energy.

It is said that the ocean market is capable of generating around 700 billion € in the Europe by the end of 2050. The globally installed ocean energy had said to be doubled from the range of 10-MW in the year 2016 to around 30 MW in 2017. The tidal forces proceed with extensive amount of water. The winds which move at a high velocity help build up huge waves. The amount of energy that can be extracted from the wind, currents and the waves contain 200 times more energy than that which is at this stage being absorbed by the humans. [8] The key renewable marine energies are:

1) Wave Energy
2) Tidal Energy
3) The energy that is derived from the temperature differences at the oceanic depths also called (OTEC).
4) Osmotic power (which is the energy obtained from the difference in the content of the fresh water and the saltwater)
5) Wind energy
6) Ocean current energy

2. The principles and physics of Tidal Energy

Tidal power is said to be a source of power that helps convert the energy that is obtained from the tides into a means of power generally electricity. The tidal power is obtained from the oceanic tides of the Earth. They are periodic variations which are gravitationally exerted by the celestial bodies.

As the Earth tends to spin around its orbit, the rise in the ocean water collides with that of the water present at the shores which are lightweight and this in turn creates a tide. These forces are the ones that generate the corresponding motions or also the currents in the world's oceans. These impregnable attractions towards the oceans causes a rise in the level of the water which causes a rise in the increase of the level of the sea. These motions take place due to the congruous movements of the moon around the earth about its orbit. The change in the magnitude and the nature of this movement contemplates the positioning of the Moon and the sun around that of the earth. [9]

The movement of the sun and the moon mainly cause the attraction of the water sources. The force exerted can be calculated as:

$$F = \frac{k \times M \times m}{D^2} \qquad \text{Eq 1}$$

Where:

F – Force of attraction

K- Universal Constant of Gravitation

M- Mass of the moon/ sun

m- the mass of a molecule of water

D- the distance of the molecule of water to the sun or moon

The differences in the maximum and minimum levels of the water within the half period of the day is termed as semidiurnal range. This is considered to be a two weeks cycle.

In gradual cases, the moon is said to be the one playing the higher role than the sun. The force of gravitation between the amount of water and the moon creates a torque which decelerates the rotation of the earth. Also, with the help of this force, the acceleration of the movement of the moon around the sun tends to increase due to this. The effect of that bulge of water is said to be denser on the side of the earth side which is closest to the moon via the effect of the gravitational force. [10]

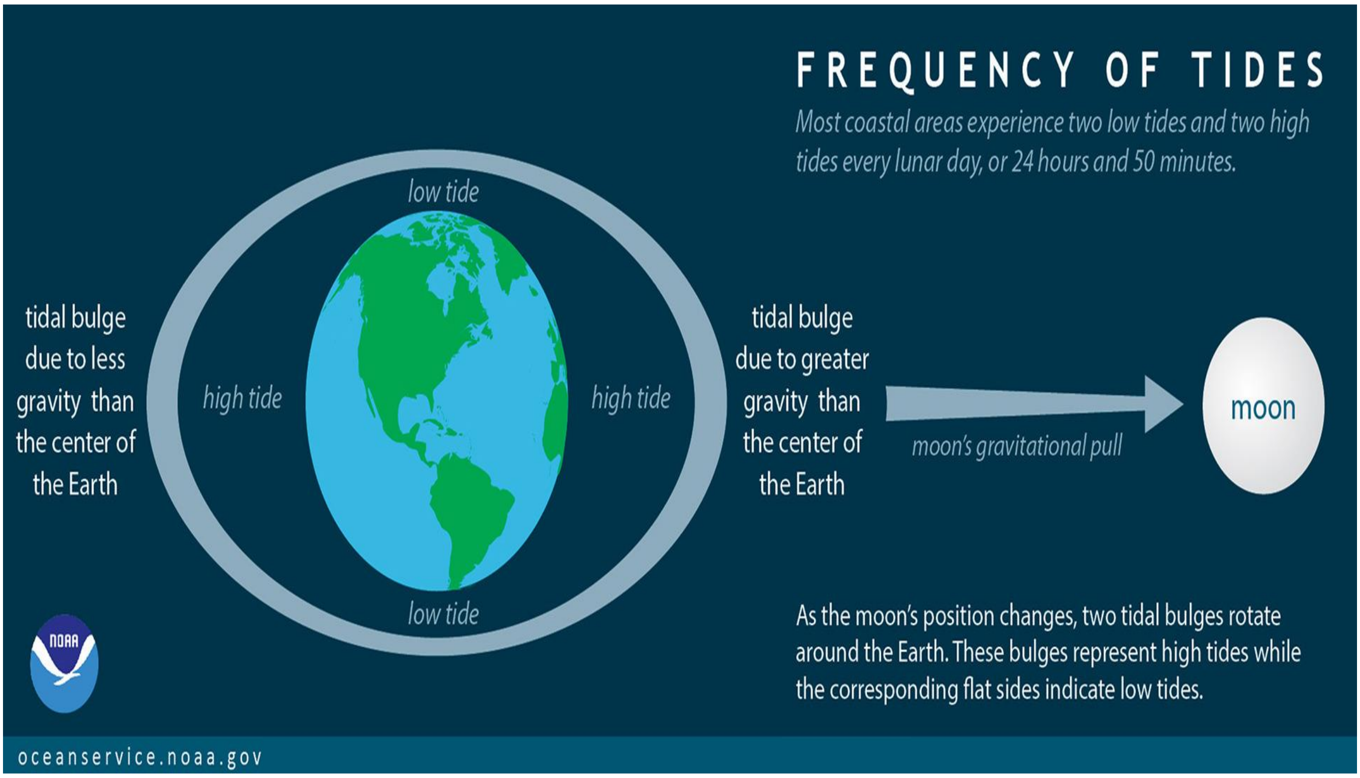


Figure 1 Explanation of high tides and low tides [10]

During the period of full moons- which mostly occur during the stages when the earth, sun and the moon are almost aligned together the average tidal ranges are considerably bigger. This is said to occur twice every month. The moon appears to look new when it is placed directly between the sun and the earth. On the other hand, the moon appears to be appearing larger in size when the earth, is said to be placed between the moon and the sun.

Therefore, in both the cases, this tends to double the gravitational pull of the sun to that of the moon on the earth, which leads to the increase in the rise of the ocean more than it is normally. This is what can be described as the spring tides which means that the low tides are lower than average compared to that of the high tides. These occur twice every month, irrespective of the season

After the passing by of seven days, the positioning of the sun and moon are at 90° to each other. During this period, the rise of the water that was caused by the moon is cancelled out by the rise in the water which is caused by that of the sun. These middling tides are termed as neap tides.

Hence during the period of neap tides, the low tides are said to be at a higher position than that of the high tides. These tend to occur along the first and the third quarter moon, when we see that the moon appears to be half full. [11]

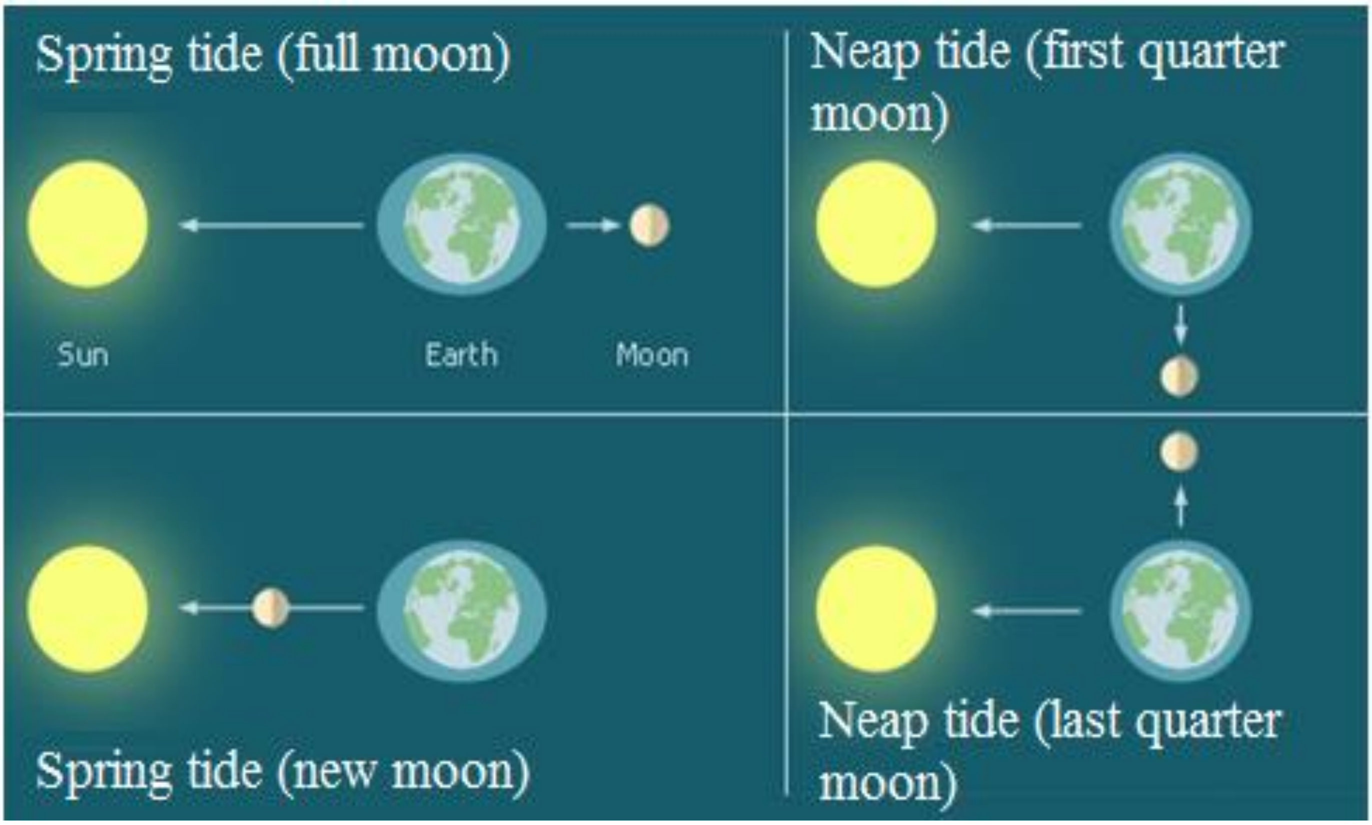


Figure 2: The diagram of Spring tides and Neap tides. [12]

2.1 More types of Tides

Semi-diurnal Tides- When compared to the amount of high tides and low tides, with respect to the relative heights each tidal day, tides can be described into three types. One of them being semi-diurnal. The movement of the moon when it is directly centred above the equator. In theory, most of the locations on our planet excluding those at peak altitudes would turn through the two tidal bulges and see changes and observe two equal high tides and two equal low tides per day. This is what they call a semi-diurnal tide. The Semi-diurnal tides are said to have a period of around 12 hours and 30 minutes. Along with that, they have a wavelength of more than half of the circumference of the planet. [12]

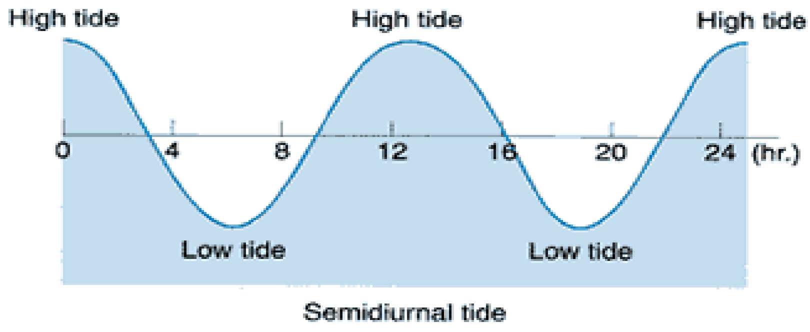


Figure 3: Semidiurnal tide [12]

Diurnal Tide- There are occurrences of various types of tides when the moon is said to be on the north or along the south of the equator. As we see above that the semi-diurnal tides are experienced at the equator at all times. When we observe most of the locations which are on the north or the south of the equator, there occur two unequal high tides and also two unequal low tides every tidal day; which can be called as a mixed tide. The dissimilarity in the heights that we observe between the continuous high or low tides is what can be described as diurnal inequality. The placement of the moon directly above the Tropic of Cancer or along the Tropic of Capricorn, we observe the tropic tides which take place because the diurnal inequality is said to be at its maximum. The diurnal inequality is said to be at a minimum when the moon is above the almost above the equator. The Diurnal tide contains a period of 24 hours and 50 minutes. [12]

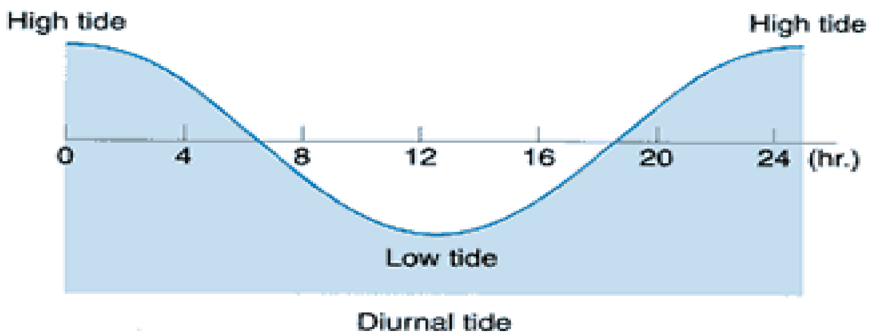


Figure 4: Diurnal tide [13]

Mixed tide- A mixed tide can be described as a tidal cycle which holds two dissimilar high and low tides. The most common being semidiurnal consisting of two equal high and low tides within a time span of 24 hour and 50-minute period. The mixed tide still has two high tides and also to=wo low tides per 24 hour and the 50-minute period. However, these tides are not common in nature. The movements are high high tide, a high low tide, followed by a low high tide and a low low tide. [13]

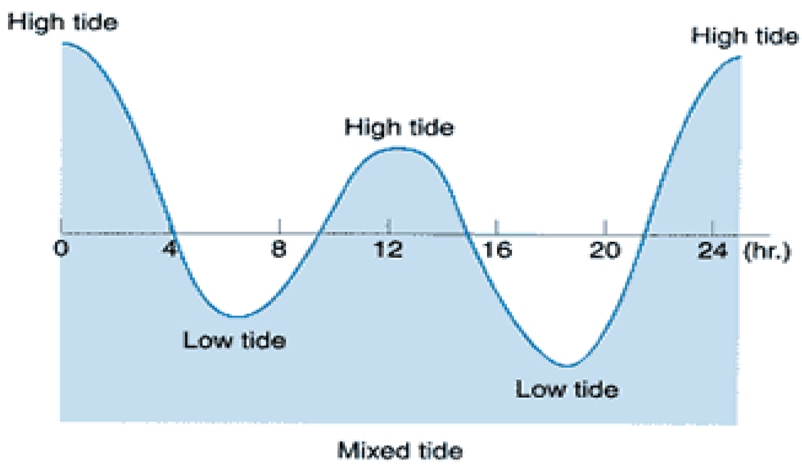


Figure 5: Mixed tide [13]

2.2 History of Tidal Energy

Tidal energy makes usage of the potential energy that is generated by the different levels of water. Tidal energy is produced by using the hydrokinetic vertical or horizontal turbines which rotate because of the kinetic energy of the water currents.

The most pivotal tidal energy plant is situated in La Rance in France. The plant is said to be located on the estuary of Ille, which is the Rance river. It was constructed in the year 1966 with the total power being around 240 MW. Being the largest of the tidal plants, during those times, it is said for it to have taken around 20 years to cover the costs of its construction. With problems involving the initial costs of investment and the impacts on the environment. It is said to be operated by the EDF and is the second largest tidal power station in the world, in terms of the installed capacity. It consists of 24 turbines with each supplying power around 0.015 % of the power demand of the France. The barrage covers distance from the west to the Briantais point in the east, being (2,465ft) long. [14] After the construction of the La Rance tidal power plat, the construction and exploitation of the tidal energy has been significant.

The western coast of South Korea, with its various sized inlets and the wide tidal range is said to be a rich archive of tidal energy. This is where the world’s largest operating tidal power station exists. The Sihwa Lake project.

The Sihwa lake is a lake artificial in nature and around 44 km^2 in size. It was constructed to help supply the reclaimed land for the nearby cities, flood mitigation and help with the irrigation purposes by helping convert the coastal water to fresh water.

The power capacity is of 254 MW which surpasses that of the La Rance. Consisting of 10 water turbine generators each with a capacity of around 25.4 MW, with the annual power capacity reaching around 552 GWh of electricity whole year. The 552 GWh of electricity that is produced from the Sihwa lake is equivalent to 900,000 barrels of oil. [15]

The currently active Kislaya Guba Tidal Power Station is said to be the largest tidal power plant in Russia. Having a capacity of around 1.7 MW. It was constructed in the year 1968. Initially, it had a generating capacity of around 0.4 MW but later in the year 2006 it was upgraded with a 1.2 MW orthogonal turbine. This is considered to be the smallest tidal power plant in the world.

The Jiangxia Tidal Power station is one of the largest power stations in the world ranking at the fourth position. It is located in the Wenling City, China. The currently installed capacity is said to be at 3200 kW and has 5 units. With the powers being 500 kW, one unit with 600 kW and the last three with 700kW making in total of 3,200 kW

In reality, there are some tidal power plants which are still in the stage of Development. With the resources being taken into consideration, along with the location, where the plants could be constructed.

The Swansea Bay Tidal Lagoon, Wales which had been one of the most exhilarating developments in the United Kingdom. It is said to have enough power to help supply electricity to 120.000 homes for around 120 years if it does end up receiving the planning approval it is in seek off.

The Incheon, South Korea is a tidal power station which was proposed for the Incheon Bay. The designing of the facility is to top 1,320 MW. It will consist of 44 water turbines which will each be rated at 30 MW each, which in turn will make this the largest of its kind in the world.

Garorim Bay, South Korea- With already having one huge project under construction and having the largest turbine under the belt. South Korea plan on another project which would have a capacity of 520 MW.

There have been many pioneering projects which are on their way to be developed for the Seven Estuary nearby Bristol. However, there are some challenges that are being faced by the opposition of the environmental groups. Until 2013, they had come to no decision.

India has been trying to make utilisation of the powers from tides as well. The main reason for a tidal power plant not having been set up yet is due to the high installation costs, along with the high cost of electricity production. Nevertheless, there have been some proposals for setting up some plants in Gujrat India.

Region	State	Tidal potential (MW)
Gulf of Khambhat	Gujarat	7000
Gulf of Kutch	Gujarat	1200
Gangatic Delta, Sunderbans	West Bengal	100

Table 1: Potential of Tidal Energy in India [17]

Moving ahead there are further sites which exist already and some which are yet to be developed completely have been shown below:

Barrage	Country	Capacity (MW)	Power Generation (GWh)	Construction costs (Million USD)	Constructio n costs per kW (USD/kW)
Operating					
La Rance	France	240	540	817	340
Sihwa Lake	Korea	254	552	298	117
Proposed/planned					
Gulf of Kutch	India	50	100	162	324
Wyre barrage	UK	61.4	131	328	534
Garorim Bay	Korea	520	950	800	154
Mersey barrage	UK	700	1340	5741	820
Incheon	Korea	1320	2410	3772	286
Dalupiri Blue	Philippines	2200	4000	3034	138
Severn barrage	UK	8640	15600	36085	418
Penzhina Bay	Russia	87000	200000	328066	377

Table 2: Estimating the costs of construction and the proposed tidal barrages

Note: They are equivalent to 2012 [17]

Site	Country	Bay area (Km^2)	Avg. Tide	Potential Power (MW)
Passamaquoddy	USA	300	5.5	400
Cook Inlet	USA	3100	4.35	Up to 18000
Mezen	Russia	2640	5.66	15000
Tugur	Russia	1080	5.38	6790
Severn	UK	490	8.3	6000
Mersey	UK	60	8.4	700
San Jose	Argentina	780	6.0	7000
Carolim Bay	Korea	90	4.7	480
Secure	Australia	130	8.4	570
Walcott	Australia	260	8.4	1750

Table 3: These are some sites with the potential for tidal power installations. [15]

2.3 Tidal Range Power

Tidal range is basically the vertical difference between the low and high tide.

The difference in the heights of the water is captured and that helps generate power due to the water that flows from the high to low, being proportional to the squared height or the (head h):

$$P(t) = \frac{1}{2}\,\rho g h^2(t) \qquad \text{Eq 2}$$

Where p= 1,023 kg/m^3 the water density

G= 9.81 m/s^2 earth´s gravity

The power produced on an average during a tide period is:

$$P = \frac{\rho A R^2 g}{2\tau}\ [W] \qquad \text{Eq 3}$$

Where: ρ = the density of the water in kg/m^3

A = Surface area [m^2]

R = the range [m]

G= the gravity of earth [m/s^2]

τ = the period of time [s]

What this formula explains to us is that, in order to increase the production of the power, what we can do is increase the surface area A of the barrage or the range R. The barrages and the tidal range have to be grand enough.

2.4 Tidal Energy Conversion Methods

We know that the energy can be obtained from tides when it comes to the movements of the water, being in vertical which is due to the rise and fall or when it comes to the horizontal motion of the water where the kinetic energy or the potential energy is extracted termed as tidal currents.

2.5 Tidal barrages

In order to generate electricity, the tidal barrages make usage of the potential energy of the tides. The hypothetical potential energy can be calculated using the following method:

$$E = g\rho A \int z dz = 0.5 g\rho A h^2 \qquad \text{Eq 4}$$

Where:

E: energy (Joule)

g: acceleration due to gravity (9.8m/s^2)

A: area of the sea (m^2)

ρ : density of the seawater (roughly 1022 kg/m^2)

z: the vertical coordinate of the surface of ocean (m)

h: tide amplitude (m)

It is important to know that the (gp) for seawater = 10.0156 kNm $^{-3}$

This method is widely used in the tidal ranges to help convert into electricity. What we realize is that the production of electricity is not constant due to the constant need of head required on the either sides of a dam. On the bright side, the production of electricity can be predicted.

3. Conversion of energy from Waves

There are different methods to help extract the energy from waves. The system to obtain the energy from waves arrives from the wave motion and depends on the height of the wave and the period.

The waters present in deep seas generate large flues and the conditions are predictable. The energy E(Wh). Which is the wavelength towards the direction of the wave is given by:

$$E = \frac{1}{16}\frac{pg^2}{\pi}\left(H^2T^2\right) \qquad \text{Eq 5}$$

This is what we know as the total excess of energy in the continuous motions in waves in deep waters.

Where:

P: density of sea water (kg/m^3)

g: is the gravity acceleration (ms^{-1})

h: height of the crest of wave water (kg/m^3)

T: time period (s^{-1})

Whereas, the power P per unit of width when it comes to a wave front is given:

$$P = \frac{1}{64}\frac{pg^2}{\pi}\left(H_s^2 T_e^2\right) \qquad \text{Eq 6}$$

Where:

P: W/m

H_s: height of the significant wave in (m)

T_e: Time period of the wave

4. Different Technologies for Tidal power

There are currently three different ways to generate tidal energy

1) Tidal streams
2) Tidal barrages
3) Tidal lagoons

4.1 Tidal Streams

Tidal generators, turbines are said to be placed in tidal streams. A tidal stream can be considered as a rapid moving body of water which is created by tides. Since water is denser than air, tidal energy is more robust than wind energy.
The turbines come in various shapes, but a few looks similar to those of wind turbines. Being very similar in nature than it is to hydroelectric power generation. In cases when the turbine is capable of circuiting in forward and backward directions, then there will be more energy produced.

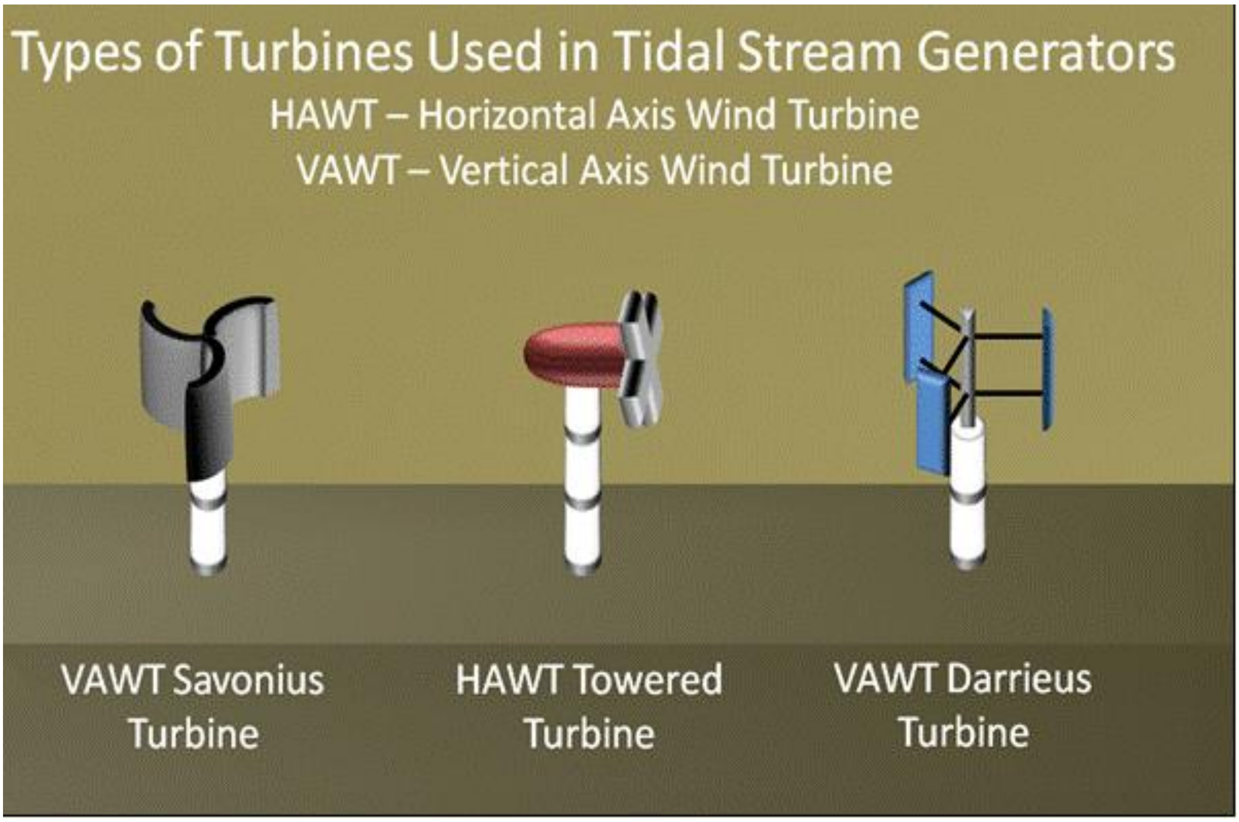


Figure 6: Types of turbines being used in tidal stream generators [18]

The advantages they have are that they are very cost effective and economical to execute. They are cheap due to the fact that the turbines can stand on their own requiring no support for an enormous dam as in the barrage systems.
The disadvantage being that they cannot produce the same amount of power when compared to the barrages. They are also very much prone to corrosion. With the latter being a minor problem. [18]

4.2 Tidal Barrage

This is a form of marine energy generation which makes usage of long walls, sluice gates to capture and store the potential energy of the ocean. The erection of the walled dam is what we call ¨tidal barrage.
The functioning of a tidal barrage is very simple. The barrage is made of reinforced concrete walls and they are standing on an estuary, bay or on the inlet of an ocean. The one that restricts the water is are the sluice gates which can be opened or closed. During the period of low tides, the gates remain open allowing the water to enter, waiting for the period of high tide.
During the period of high tides, the gates close not allowing the water to pass through them to the ocean. The water is allowed to only pass through particular channels that pass via a turbine, hence generating power.

1) Single basin tidal barrage

In this type of tidal plants, the powerhouse is said to be placed at the jaws of the basin. It is only during the discharge of the water from the basin during periods of low tide that the hydraulic turbine in the powerhouse is said to operate. But this operation has a disadvantage for not being continuous and rather intermittent in nature. With the filling of the basin taking place only during high tides.

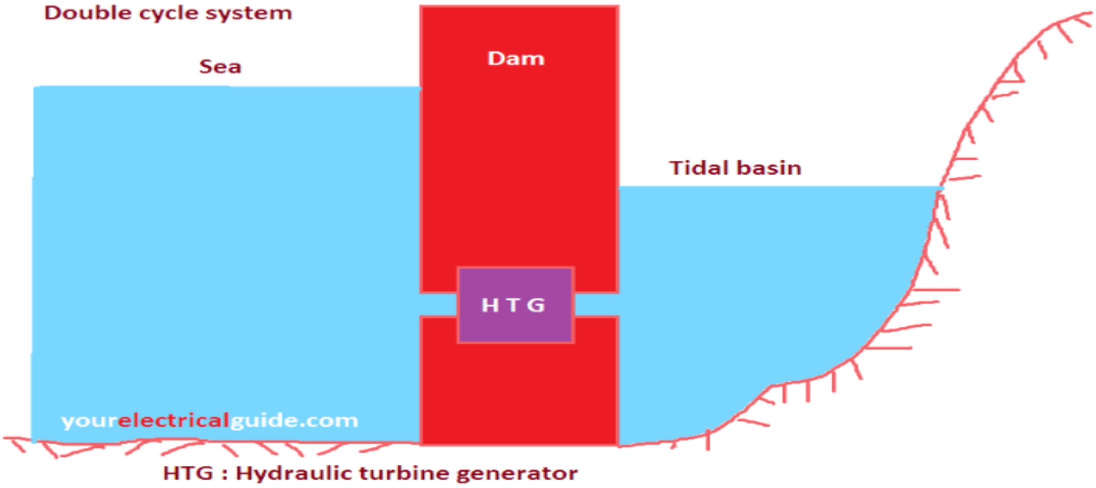


Figure 7: Hydraulic turbine generator [26]

2) Tidal Barrage flood generation

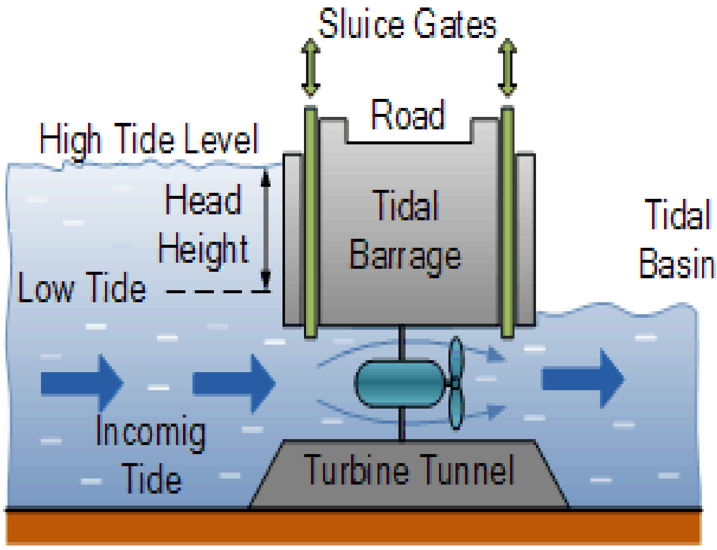


Figure 8: The function of the basin and head [19]

The basin as shown in the figure above is filled via the sluices until the period of high tide. After a brief period of time, the gates are closed. The gates are kept closed until the period of time till there is a drop in the sea level. This is important to be able to create a certain amount of head across the barrage. Further, the gates are opened in order to be able to generate power until the period of time that the head is low again. Again, the sluice gates are opened, the turbines disconnected and the basin is filled once more. These are repeated with the tides. The name is given to this process due to the generation that takes place as the tide changes tidal direction. [19]

3) Tidal Barrage Ebb Generation:

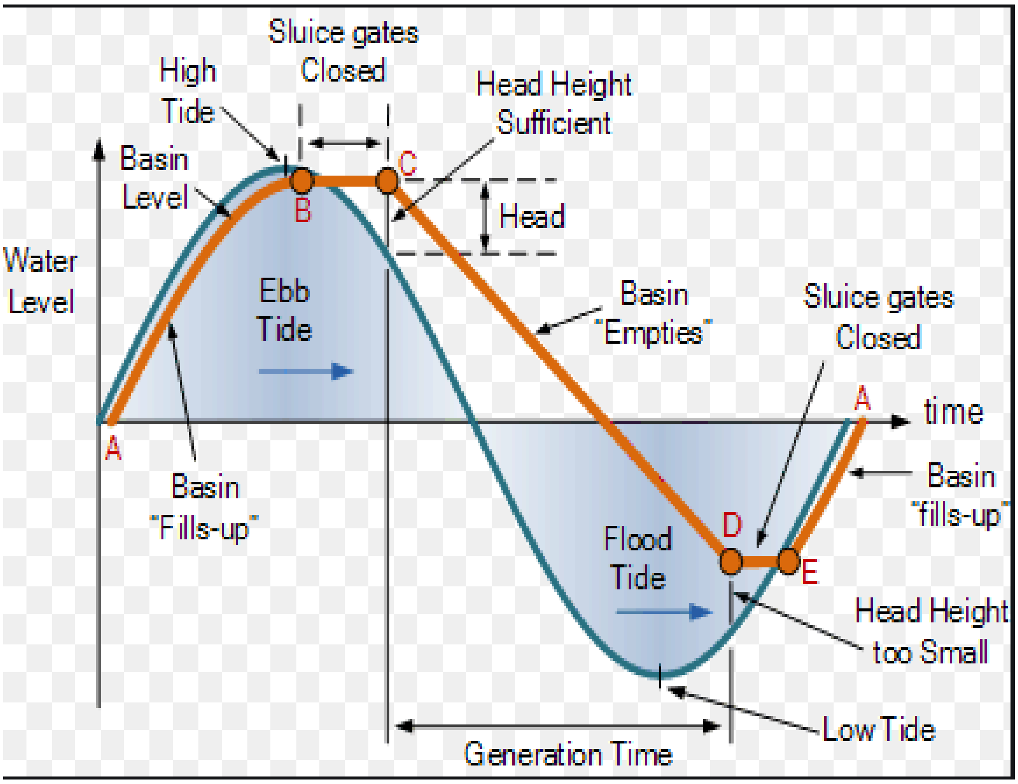


Figure 9: Working of tidal barrage ebb generation [20]

The filling of the basin takes place via the sluice gates which occur during periods of high tide. This is when the gates are shut which leads to the water being enclosed inside. While the water is trapped inside, additional amount of water can be pumped inside when the demand is not high and usually this takes place at night when the price of electricity is low. [20]

The gates are not allowed to open until the time the tide has ebbed abundantly to help develop a substantial hydroelectric head across the barrage. Then the water is later allowed to flow out via the low-head turbines, which help generate electricity for a certain number of hours till the time the hydrostatic head has dropped to a low level when the turbines are capable of functioning well enough.[20]

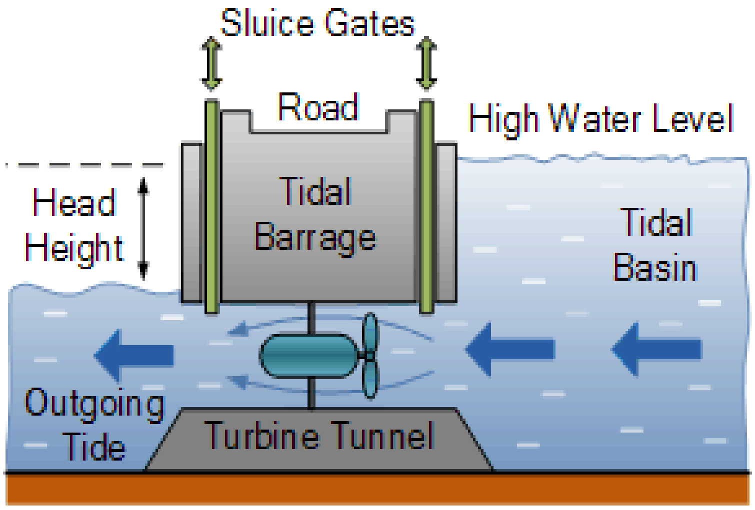


Figure 10: The function of sluice gates [20]

With the opening of the sluice gates, the turbine is detached and this leads to the filling of the basin. This repetition is what we know as ebb generation. [78]

4.3 Tidal barrage flood generation

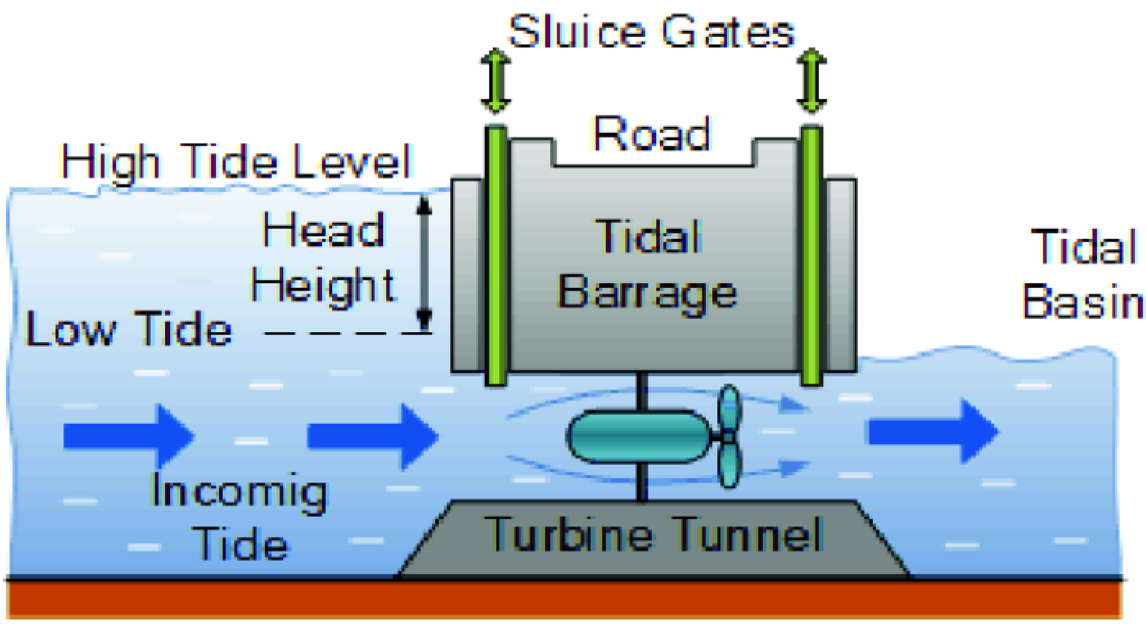


Figure 11: Working of tidal barrage flood generation [19]

The process of flood generation is considered to be the opposite of that of the ebb generation and is also less structured. The filling of the basin takes place via the turbines, during the period of flooding tide.

Due to the difference between the sea side and that of the basin side, the difference that these two have in height is differential and reduces way more rapidly than in the outflow generation. When the tide turns up and starts to come in, the gates are closed and the barrage that holds back the rising of the water level of the sea, creates a difference in height which takes places between both the levels of water placed on either side of the dam.

4.4 Tidal Lagoon

A tidal lagoon is known as a power station which helps generate electricity from the fluctuating tides. They have an indistinguishable way of working to a tidal barrage by utilising a large volume of water behind an artificial structure and then passed via a turbine to produce power. The difference being that the structure spans an estuary completely along a straight line in case of a barrage, whereas, a tidal lagoon encompasses an area of the coastline with a high tidal range backing a breakwater, having less impacts on the environment.

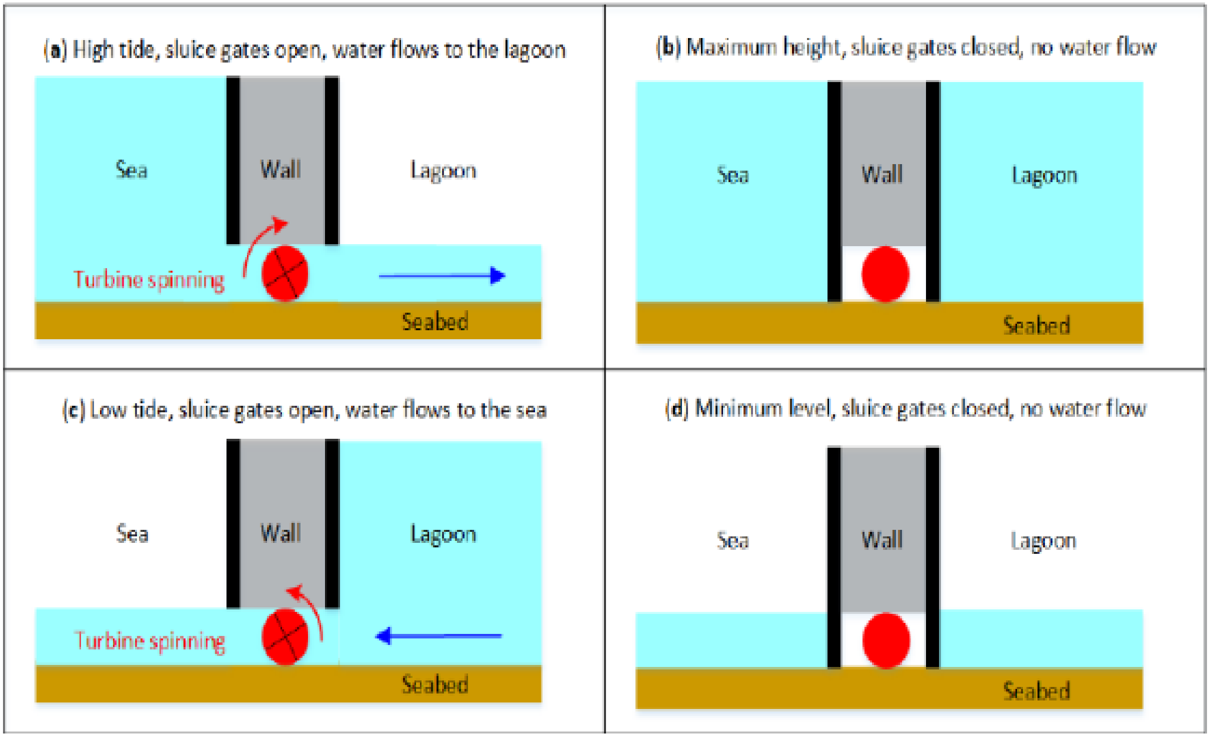


Figure 12: Tidal lagoon working principles [25]

With the entering of the tides, the water is stopped back by the turbine's wicket gates, which help control the flowing of the water which passes through the turbine. The flow can also be completely stopped from entering the lagoon. This is what creates the difference in the head between the inside of the lagoon and the sea. Then the most can be made out of the difference between the heights when the water flows through the turbine housed inside a section of the breakwater wall. With the spinning of the turbine, electricity is generated. [24]

4.5 Types of Turbines

As it has been mentioned before, turbines are considered to be one of the main components for the production of power and generating electricity. The choosing for a typical type of turbine depends on the different types of variables. Such as, the head, flow rate, the pumping operation and also the design of the turbines.

These days, there are different types of turbines accessible these days.

1) A bulb turbine can be considered similar to the Kaplan turbine. In the bulb turbines, the generator is confined and enclosed inside of a streamlined steel housed watertight space which is at the centre of the water passageway. The variable pitch propeller is responsible for the driving of the generator and situated on the downstream towards the end of the bulb. However, the difference between the Kaplan and the Bulb turbine being that the water that enters and leaves this unit has diminutive change in direction. The design being robust helps provide more flexibility. The servicing can be difficult to do since they require distinct air circulation and cooling which takes place within the bulb. [27]

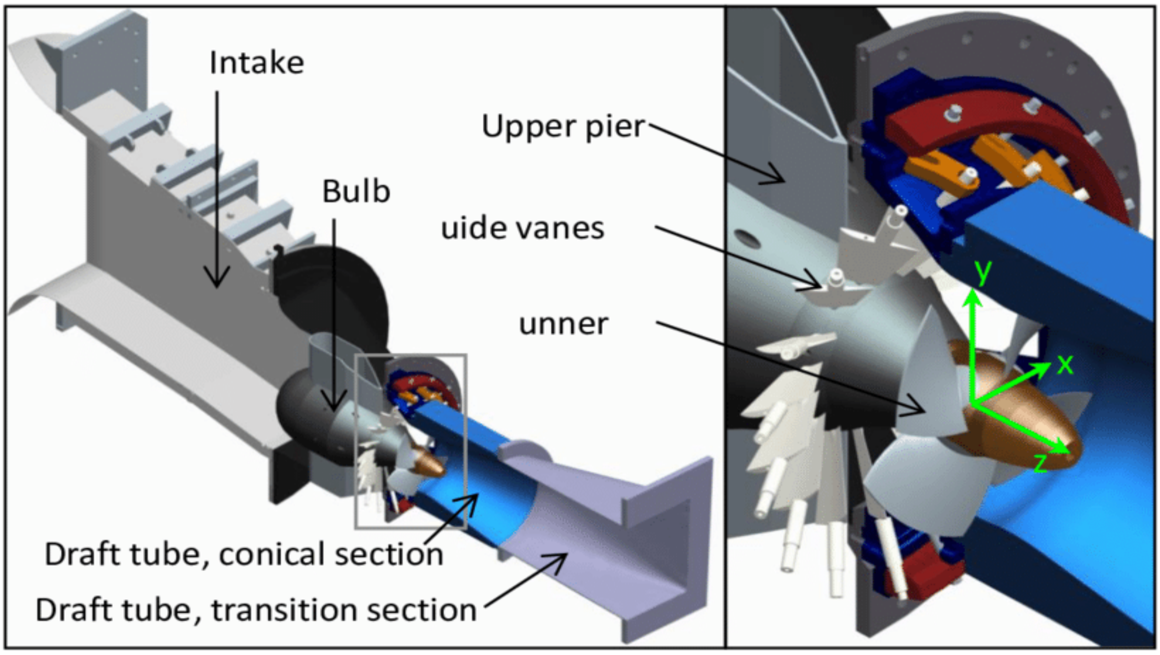


Figure 13: A bulb turbine [28]

There are more than hundreds of bulb turbines which are placed and currently in operation all around the world. With more than 25 having been deployed in China in the last ten years. Some known ones being The La Rance (France), Rock Island (USA), Paldang (South Korea), Chang Zhou (China), Qiao Gong (China) and Jirau (Brazil).

2) Rim Turbine

In a rim turbine, the generator is separate from the turbine. The placement is on the torrent and associated via a pole which moves along the turbine. Which leads to the turbine being in the water stream. Along with that, the rotor is protected from the opening of the ocean water in particular planned water seals. [29]

With the support required, it is also important to bar them when the uptake of the turbine is required, in spite of the fact that the generator can be accessed when the entry of the water is shut and the depletion is off.

They are currently in operation and deployed. A 20 MW Straflo turbine is in Canada.

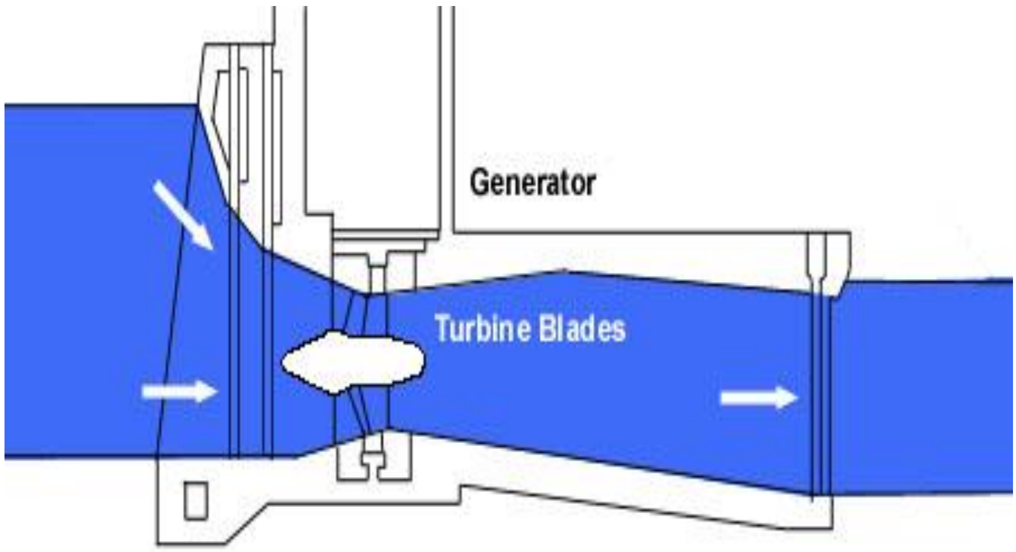


Figure 14: A rim turbine [80]

3) Tubular turbines

Unlike the rim turbine, in a tubular turbine, the generator is said to be mounted at the highest point of the flooding of water with a 45-degree angle with the turbine. Also, they are said to be integrated to a long shaft.

The positioning is such that it turns in the favour of the turbine and the cutting edges help provide stability. This further insinuates that the demand of power can be adapted to with the change. The smaller edges tend to furnish more power and the higher ones turn out to create more power. [29]

The turbine does not require much space such as the other turbines. The small size of the powerhouse and the superficial requirements of the draft tube, which are correlated with the wicket gates and also the runner blades, both being adjustable.

They make the perfect utilization of the tidal and hydraulic power because of having extremely low heads and exceptionally large flow rates. In addition to that, they have a large discharge, high efficiency and they do not require much excavation. [30]

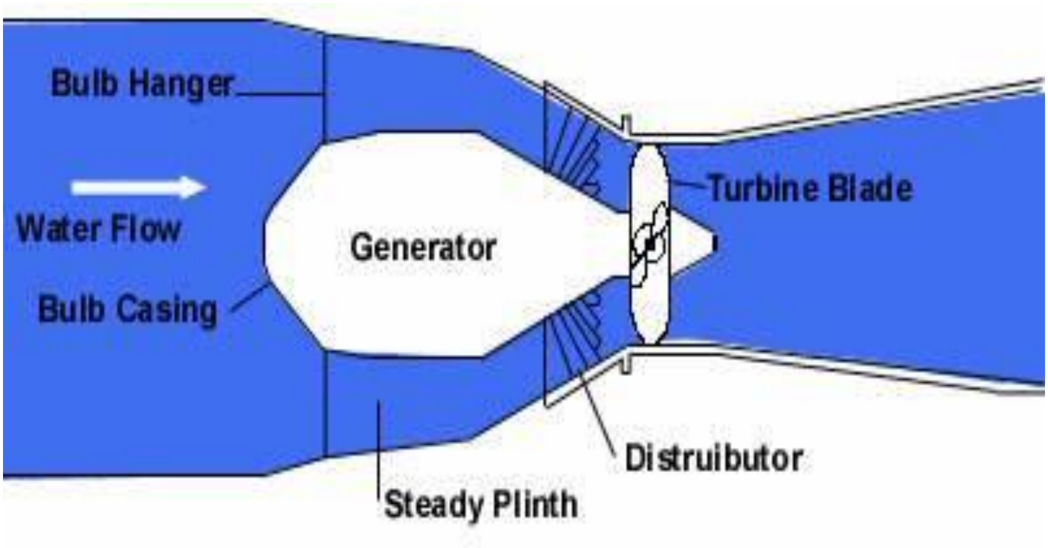


Figure 15: A tubular turbine [81]

5. Tidal Currents

Tidal currents are what can be called as the recurring flowing of water which is driven with principal, they are not necessarily exclusive. Being oscillating makes them predictable. The external forces such as the non-periodic can be applied to tidal currents depending on the weather conditions such as the tides which can be radiational, internal or the geographical. [31]

They are a form of Kinetic energy. Being very much similar to the wind turbine, the difference lies in the density. With water being 800 times denser than air. Tidal currents have a very low environmental impact. The tidal devices are more or less completely placed under the water. They occupy very little land space and are considered to be functioning in a safe environment. There could be some problems faced while trying to install the tidal devices since they are installed under the water.

Tidal turbine devices have to be installed in away such that they can function properly with frequent servicing. The reason being that they face large forces unlike the wind turbine. The forces mainly being related to bending forces and not the lifting forces which are related to gravity and centrifugal forces in the case of wind turbines.

Though the cost of the technology is high, it will decrease in time with further improvement in technology. The maintenance, installation problems, the transmitting of electricity and the impacts on the environment affecting the costs.

The movement of the earth being important such as that the Coriolis forces alter the movement away from the equator.

5.1 Ocean Currents

They are features in the environment which are abiotic in nature. Being uninterrupted in nature and directed flowing of the ocean water. They are driven by the winds, the density of the water and the tides. They are all equally responsible for the movement of the tides. As mentioned before, the Coriolis Effect also has an influence on the ocean currents. [32]

6. Surface Currents

The movement of the water is mainly due to the winds which blow in a particular pattern due to the spinning of the planet and the Coriolis Effect.

Surface currents flow in a similar pattern but not all are the same. There are some which can be coarse and steep. Whereas, some are facile and wide. The size and shape of the floor of oceanic floor can also cause an effect. The Surface currents can also tend to be grand. Such as the Gulf Stream which tends to carry 4500 times more water than that of the Mississippi River. [33]

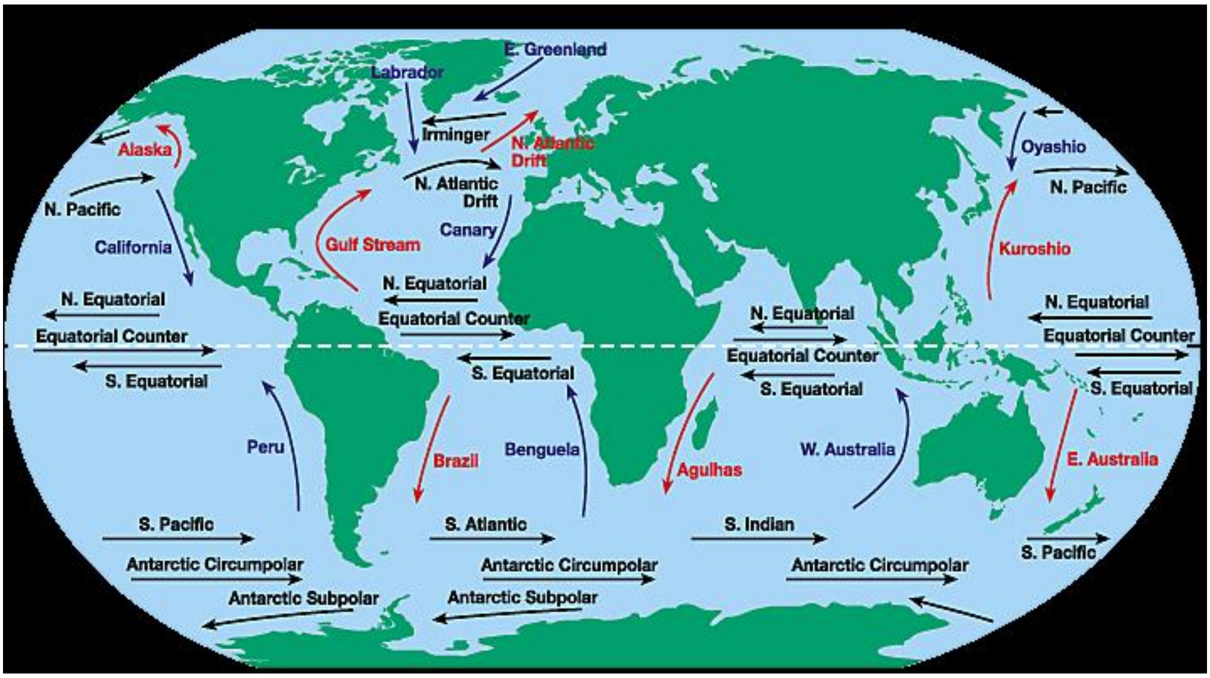


Figure 16: The surface currents across the world [33].

6.1 Deep Ocean Currents

Deep ocean currents present in the ocean are mainly caused due to the substantial sinking of surface water. The top layer of water is called the surface water. The sun can easily access this layer of water and also evaporate a little of it.

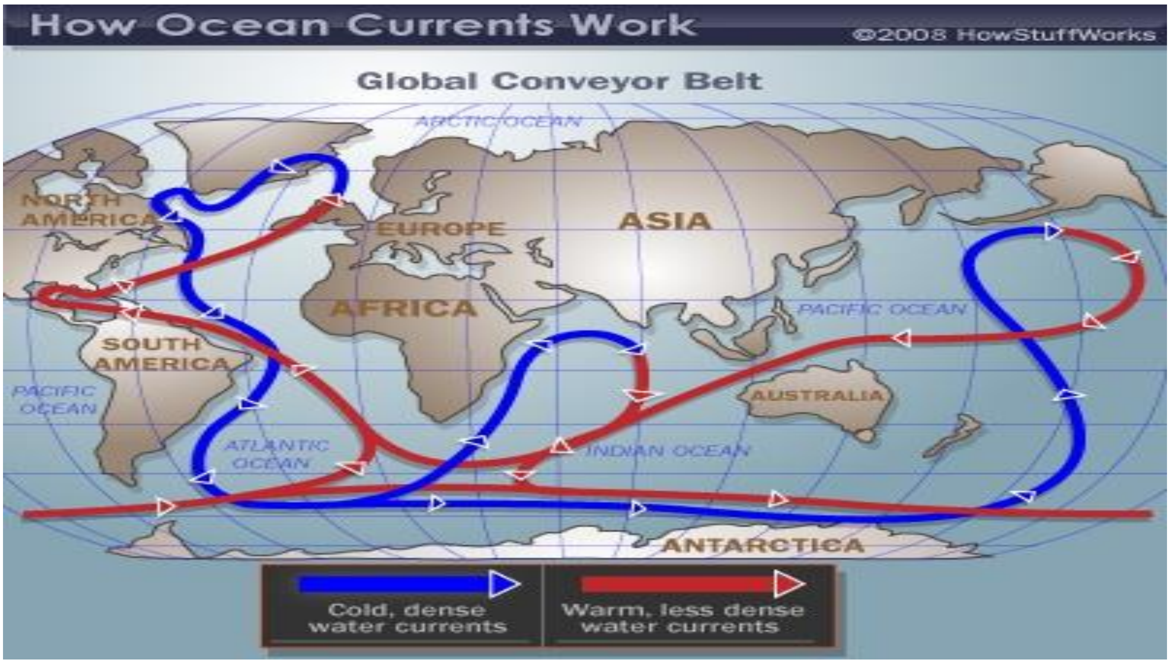


Figure 17: Deep ocean currents [35]

The cooling of the water and the lower temperature along with the presence of salt makes the water denser than the water which is present right below it. Therefore, this leads to the sinking of this layer of water further down to the deep-water layers below. This process if known as thermohaline circulation. This process tends to cause deep currents in the ocean.

6.2 Different tidal current altering devices

As mentioned before, the tidal current devices convert the kinetic energy from the currents to help produce electricity. There are a few devices in the market but two are of utmost importance, horizontal axis turbines and the vertical axis turbines.

1) Horizontal axis tidal current devices:

The horizontal axis turbines draw out the energy from the current of the flowing water in a manner similar to that of wind turbines from the moving air. As the name suggests, the rotors of the turbines rotate about the horizontal axis to generate electricity. [35]

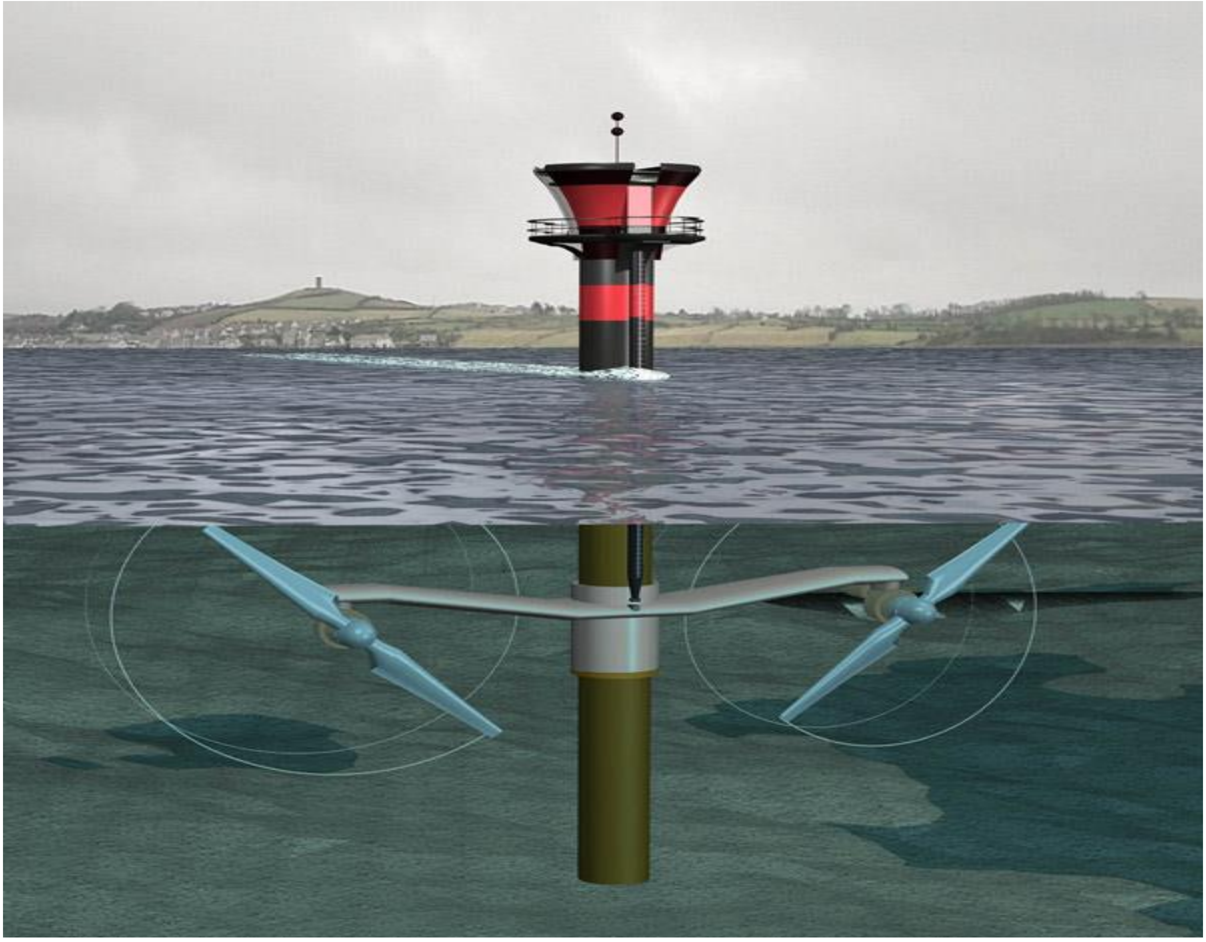


Figure 18: Type of horizontal axis tidal turbine [36]

These devices are the more widely used even though they would be requiring a mechanism for making changes to the blades. There are many different methods which include the ducts, rim generators and also the variable pitch blades. These devices generate electricity by the rotating of the blades moving parallel to the direction of the water.

Below are the examples of the live projects where they had been employed before

1) OpenHydro- The OpenHydro was called the first developer to make utilisation of the tidal test site situated at the Fall of Warness which off the island of Eday where they developed a 250 kW open centred turbine which was installed in the year 2006. This was known to be the first tidal turbine which was connected to the grid in Scotland and afterwards became the first to help generate electricity successfully in the UK. This was where the trend began from. After this the company had announced more major projects in Europe and the North of America. [38]

Figure 19: The OpenHydro project [38]

2) Sea Gen- SeaGen is a (TEC) which was developed by Marine Current Turbines (MCT) Ltd. It is said that initially they came up with a prototype which was rated at 300 kW and had been set up in Lynmouth in the United Kingdom. The operational phase was during the years 2003-2006. [40]

Figure20: The project of SeaGen[40]

However, they ended up moving to a full-scale technology with a rated output of around 1.2 MW. They are an in-stream tidal energy converter which constitutes two horizontal axis turbines which include a full blade pitch control.

Also, the blade pitches are capable of controlling a 180-degree technique which makes drawing out the energy first class. With this technique, it also is capable of functioning in a flood and ebb (MCT). Along with that, it contains a central column which can be attached to the sea bed which takes place either by means of a monopole or a Quadro pod foundation. [39]

The project had been studied for three years and reviews were made upon its impact on the environment with installation and operation also being noticed.

7. Vertical Axis Turbines

Vertical axis turbines draw out the energy from the tides in a manner similar to that of the above. Nevertheless, the turbine however is mounted on a vertical axis. The currents of the water help rotating the rotors about the vertical axis and this helps generate electricity. [35]

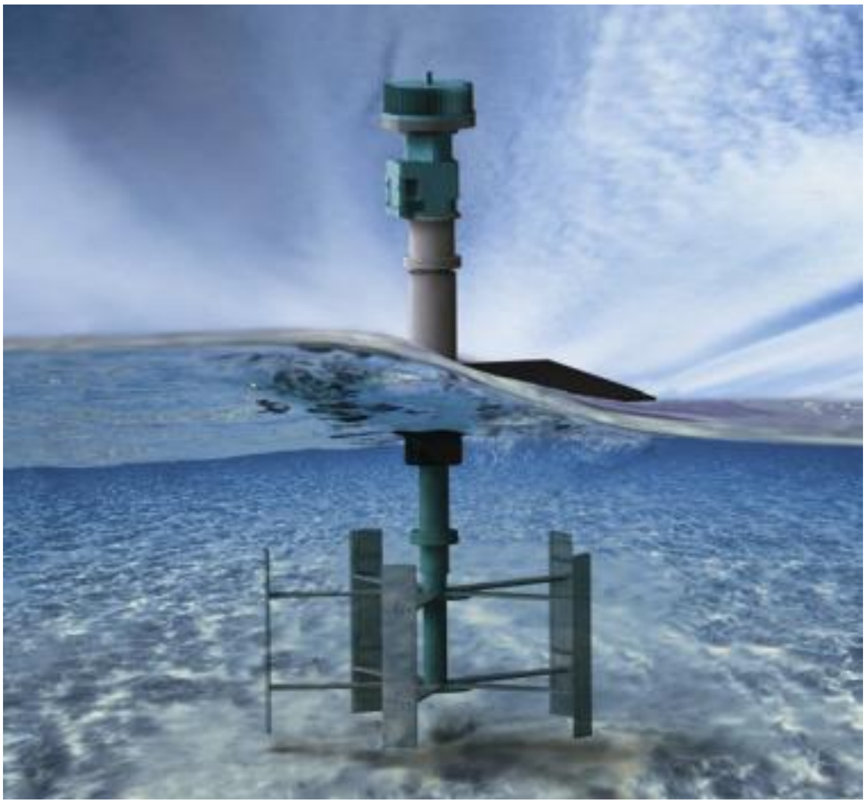


Figure 21: Vertical axis turbine type [37]

These are also known as cross flow turbines since the direction in which the water flows are across the rotation of axis. The working principle is via the vertically oriented rotor which helps relay the torque directly to the surface of the water and not requiring any complex transmission systems. The advantage that this system has that it can help extract energy of the tidal flow from whichever direction. With the disadvantages being related to stability and facing a lot of vibrations.

Here are some examples of some projects where vertical axis tidal turbines were deployed:

1) Kobold tidal turbine

The Kobold turbine is said to be a hydraulic vertical axis turbine which incorporates free oscillating blades. The year it was patented in was 1998 by an Italian company named Ponte di Archimedes International S.P.A. With the main characteristics involving rotation, it can operate independent of the direction of the current. Thus, making it flexible, floating and with a high starting torque making it self-starting.

The Kobold turbine helps generate mechanical power by making use of the marine currents. The turbine is arranged on a vertical shaft. It has been used in the Enermar Project which was located in the Strait of Messina which is along the Sicilian coast. The depth of water being at 18-25 meters and the installed capacity standing at 50 kW.

Figure 22: The Kobold turbine [41]

It was set up in the year 2001. The power which was generated was about 25 kW at 2m/s. additionally, the global net efficiency, which incorporates the electric and mechanical losses approximated at 25%. [41]

The installation site which was 150 offshore near the Messina along the Sicilian coast. The Kobold turbine was the first Marine current turbine which was said to be connected to a national grid.

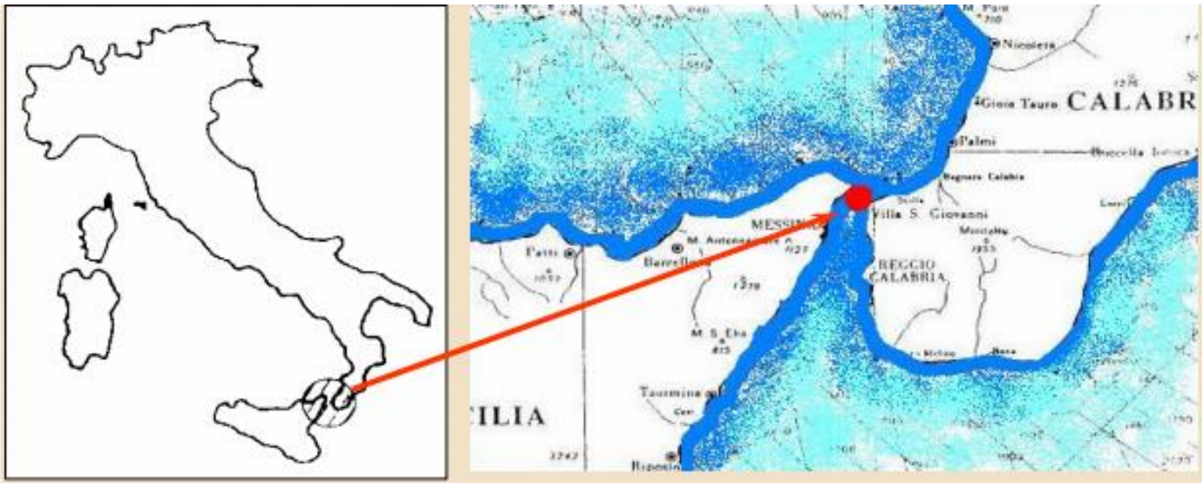


Figure 23: Screenshot of the Kobold turbine to the grid

The specifics of the Kobold turbine are as follows:

FLOATING PLATFORM	
Diameter	*10 m*
Depth	*2.5 m*
Displacement	*35 t*
Mooring blocks	*4 (35 t each)*
Blocks material	*Concrete*

TURBINE	
Rotor diameter	*6.0 m*
Blades height	*5.0 m*
Chord	*0.4 m*
Blades number	*3*
Blades material	*Carbon Fibre*

Table 4: Specifics of the Kobold turbine [41]

There were many tests which had been carried out within a range of 1 and 2 m/s. As mentioned previously, at 2m/s the power which was generated was at 25 kW (the design standing for 80 kW). (INSEAN, 2007).

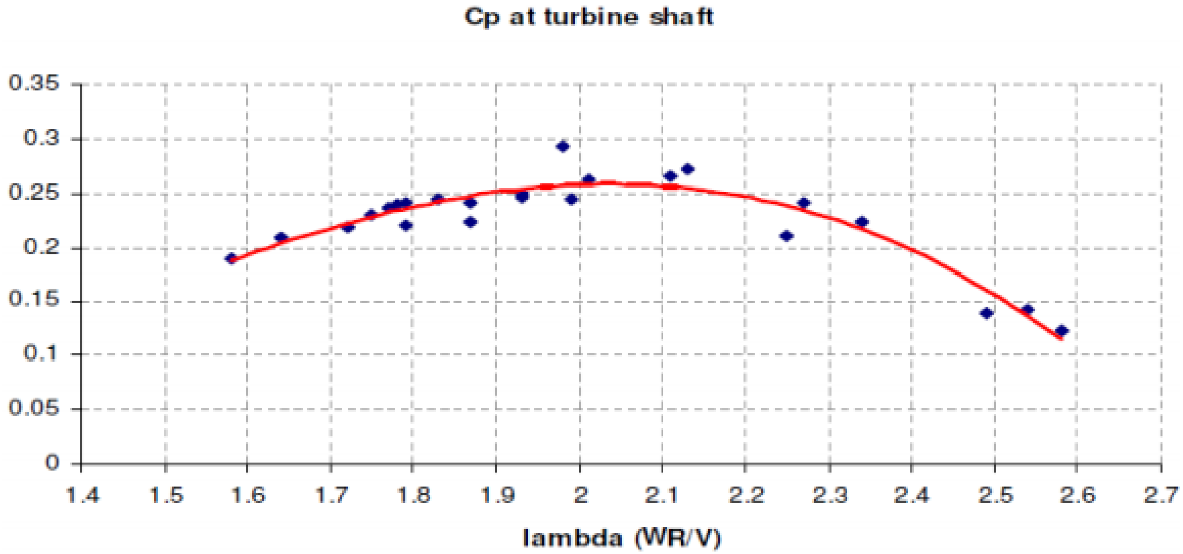


Figure 24: The Cp of the Kobold turbine (INSEAN,2007)

7.2 Oscillating Hydrofoil turbine

This type of technology varies considerably from the MEC devices. The oscillating hydrofoil turbine brings about hydrodynamic lift and the drag forces because of the existence of a pressure difference which is present on the foil section being given rise to by the relative motion by the tidal current over the foil section.

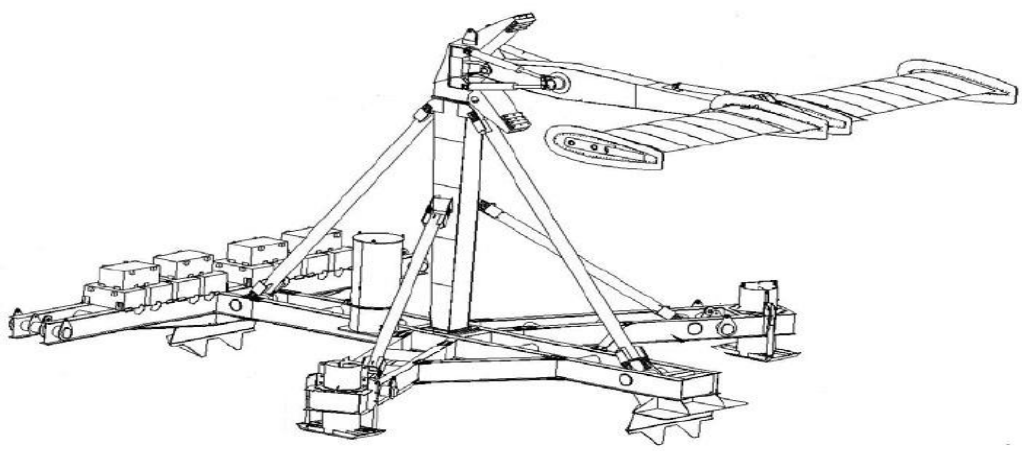


Figure 25: Oscillating Hydrofoil turbine [49]

What these forces induce are a resultant tangential force on to the fixing arm which in return drive a reciprocating hydraulic rams pump, the previously mentioned high pressured hydraulic fluid to help turn a hydraulic motor and the electrical generator. The angle of the tides decides the rise and fall of the hydrofoil in an oscillating motion. The flow of velocity and density are what the lift is dependent upon. [49]

Below is an example of where the oscillating hydrofoil has been used:

The Stingray is what can be described as an oscillating hydrofoil which alters the movement of the angle of attack in the direction of the angle of attack towards the tidal current which can be seen in the figure below.

However, there is a periodic loss of momentum caused by the nonlinear motion, which is the consequence of an enormous degree of mechanical problem. Around 15% of the power rating of the device is bygone only to the hydraulic pressure accumulator to stop the hydrofoil as fast as it can, by altering the direction of the angle of attack and going ahead with the start of the hydraulic movement in the conflicting direction. [39]

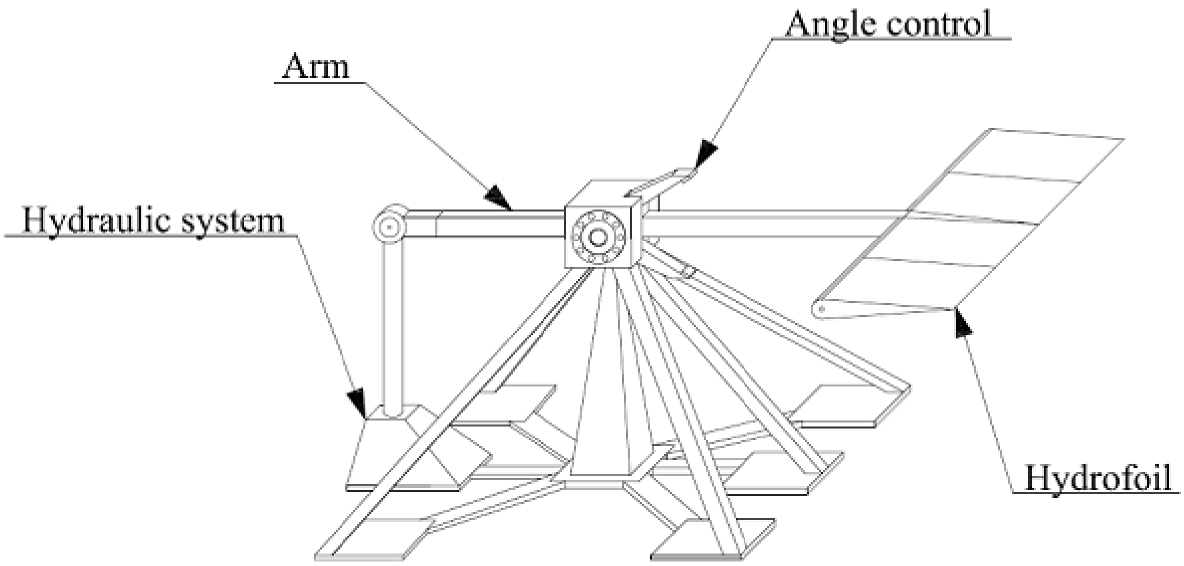


Figure 26: The system of Hydrofoil turbine

8. Potential and Future Prospects

Worldwide, the resources from the tidal energy can be considered to be largely concealed. Nevertheless, the resources globally have been estimated at around 3 TW which can be seen in the (figure below).

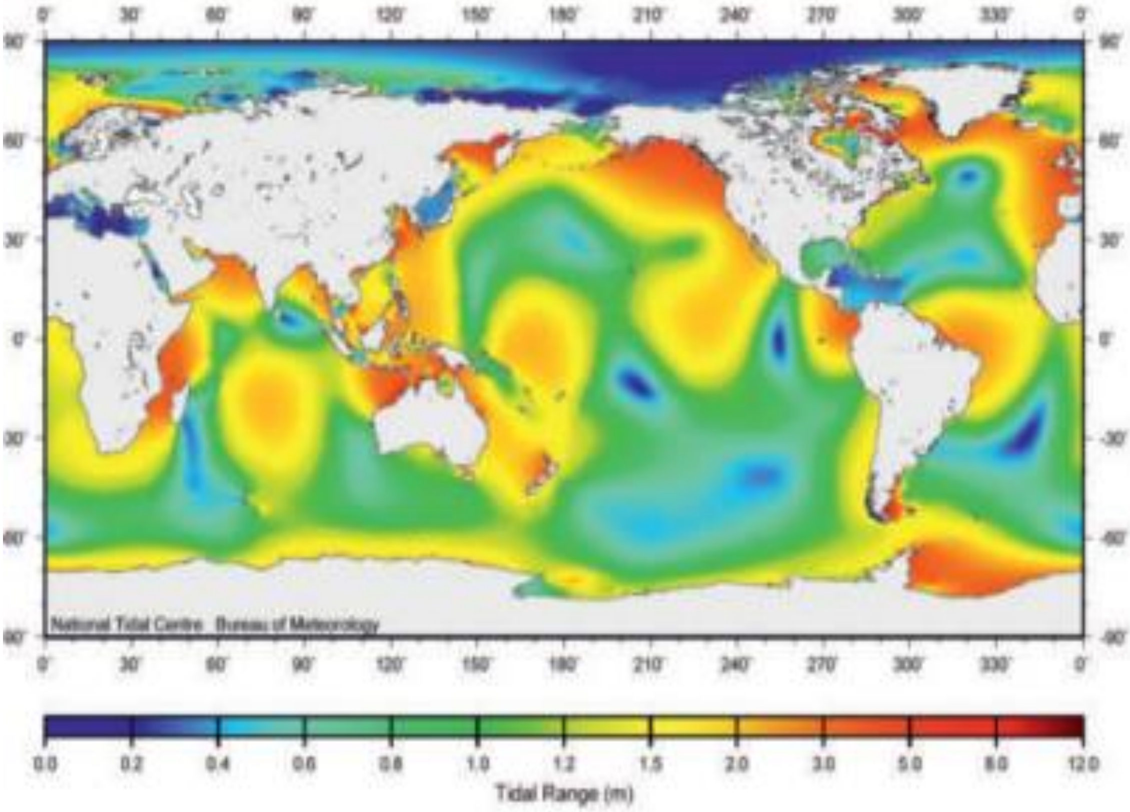


Figure 27: The future prospects globally [22].

The most important areas being close to the coast. The shape of the coast is what helps us determine the tidal range with an oscillating change which can be up to 17m within the high and low tide. Argentina, Australia, Chile, France, Japan, Russia, South Africa, Spain, The UK, Canada, China and the USA have a very high potential. All the more, Africa in the east has large resources for tidal range as well.

The tidal potential in South Korea is very high and the new projects undergoing right now can attest to that.

Figure 28: The potential of South Korea [22]

8.1. Overview and Analysis of the Maturity in Technologies

With the discussions made above, Tidal current systems exhibit a smaller variety. The sector of the technological advancement is not yet being considered to be mature enough. There are many systems which have yet not been able to identify the type of power or generator that they should be using.

There are many which are still at the concept design stage, while many are under the stage of testing at sea. There are about six wave systems and one tidal current system which has been developed as a full-sized prototype.

Whereas, Tidal barrages have been way more successful to date. When we talk about the La Rance and also the Annapolis Barrages which displays the amount of power which it is capable of generating as well as when we look forward to the long-term operation.

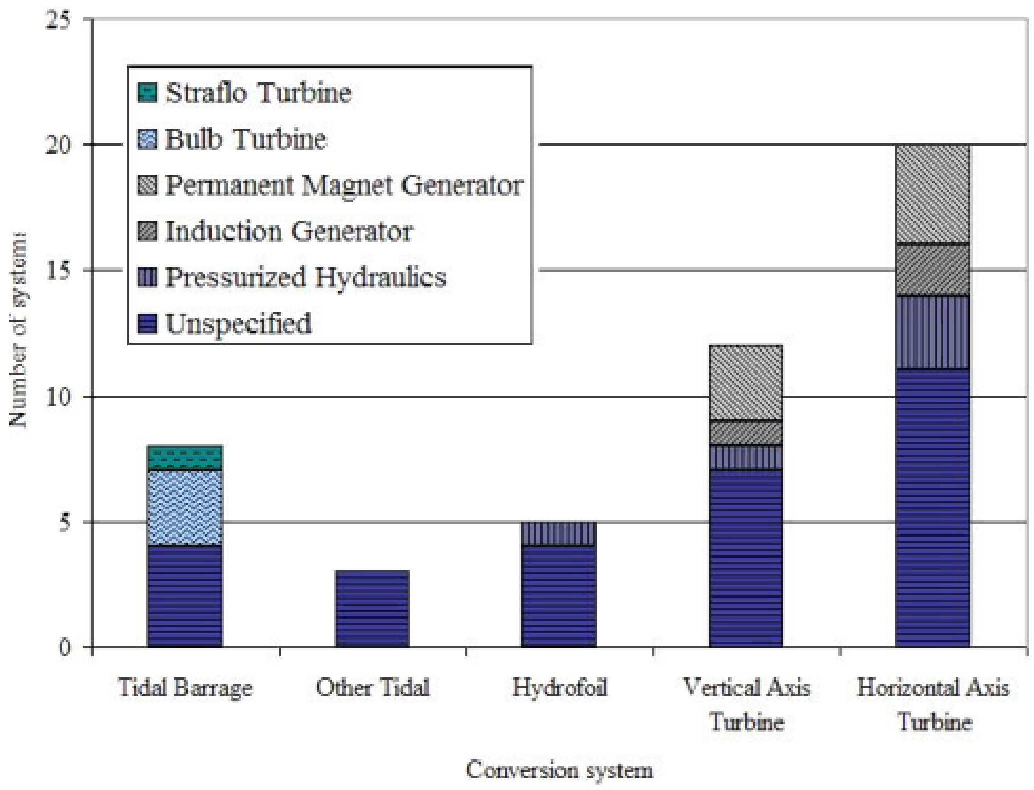


Figure 29: Comparison of the conversion system with the amount of systems [42]

Tidal current definitely proposes a great deal of promise, most importantly when it is at the initial stages. When we talk about the horizontal axis tidal turbines, the MCT seaflow, Sea Gen and OpenHydro have been the deployed ones with a 300-kW porotype and also supplying power to the local grid. On the other hand, the Vertical Axis having the Kobold turbine which has been a part of the Enermar Project.

With tidal current being almost mature and many in demonstration phase. As of today, there are many being designed and being worked on together by manufacturers such as DCNS, Siemens and Rolls Royce.

8.2. Sketch of Countries involved

With the ocean energy systems said to be widely placed across a lot of countries such as the United Kingdom and the United States of America. The UK has a lot of substantial potential and the prime when it comes to tidal energy overwhelming USA as well. [42]

Also, Canada, Norway, Australia and Denmark have some developments underway. The following figure below depicts the status.

The EU is leading the way for the ocean energy technology department and is responsible for hosting more than 50 % of the tidal energy and the home to about 45 % of wave energy developers. [44].

It was in the year 2014 when the European Commission had launched the Blue Energy Communication which depicts the contribution from the ocean energy In the Europe. Along with that, it also shows the framework for the needs to the development by the year 2020.

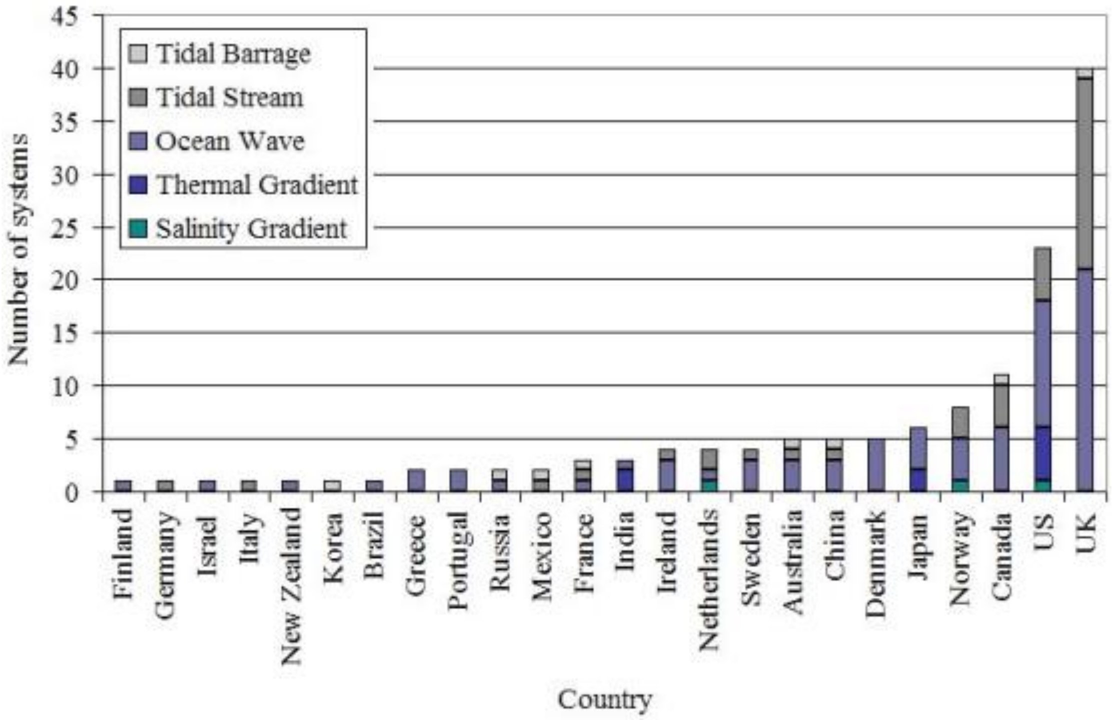


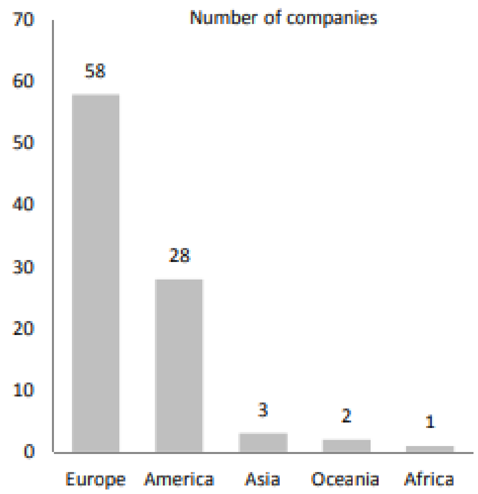
Figure 30: The countries having deployed the systems [44]

When we talk about tidal energy in general, we see that it has a certain advantage over the other renewable sources of energy because it is predictable.

With the equipment's being very much alike the wind turbines. As mentioned before the horizontal axis turbines are favoured more over the vertical axis turbines because the latter facing some limitations.

Around 58% of the developments are of horizontal axis tidal current turbines. With companies such as Alstom are a part of the development and this is the next mature technology after the offshore wind. [43]

Below is a figure which shows the number of companies which are involved in the tidal turbine development.



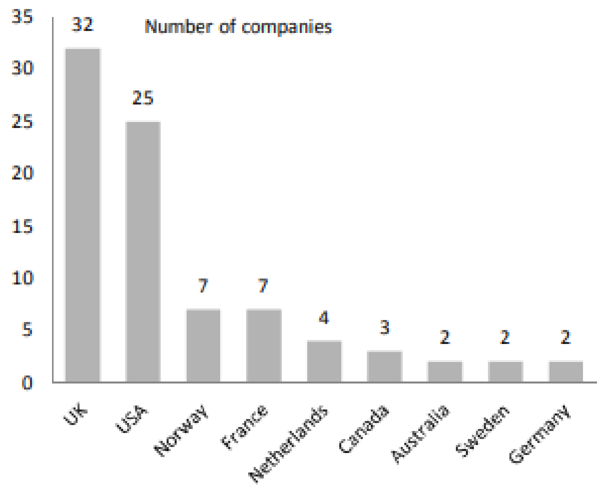


Figure 31: The investors and companies over the world [43]

8.3. The Challenges for tidal energy technologies

No matter how great the opportunities, there are always remnants to the application of tidal devices such as:

- Environmental impact
- Installation and maintenance
- Availability
- Weather conditions

1) The risk to marine life while making use of the tidal energy devices which make usage of dams or barrages can generate concerns for the environment. The dams can avert the migration of fishes and also make the slit to build up which in turn can affect the tidal basin in no positive ways.

The blades which are used can kill fishes, since the speed of turbines is slow and they have a large opening within the sharp blade. [45].

Two examples are of the Annapolis tidal plant in Canada where the presence and utilisation of acoustic signals put an end to the fish passing through the turbines. Whereas, the biggest impact of the La Rance tidal plant, France took place when it was in the installation. During that period, the estuary had to be completely closed for a period of 2-3 years.

2) The expenses at the early stage are really high due to the fact of having no benefit of manufacturing from scratch. All the devices have to be designed, manufactured and tests have to be performed in laboratories and before implemented, they have to be deployed as porotypes.

   Although, a tidal plant can be considered to be very much similar to that of a river dam when it comes to costs. But the energy produced from the tidal dam is almost less than half of the latter. The average load factor of a tidal plant generators stands at 28%. The working of a load factor helps determine the amount of the real power output which can be drawn from a capacity determined. [45]

3) Even though tidal energy is predictable, being intermittent in nature due to the tides, the availability of resources and also the places are very much limited. According to some research work, there are not more than 40 good sites on Earth where the flows are not high enough. The need for kinetic energy for turning the blades of the turbine is very much important.

   Additionally, the areas which have abundance of resource are not situated in good areas.

4) Being able to withstand the weather conditions is something of utmost importance to be taken into consideration. Being able to resist the storms, the currents and the great waves.

   The devices have to be strong enough to help produce the energy and require robustness. Metals like steel require more attention and detailing due to the corrosive nature of salt water. The availability of metals having resistance to corrosion makes the whole process even more costly. [46]

9. The Tidal Turbine development in Dundee Scotland

With the development in renewable energy and an increase in the quantity of data which is available and with the help of simulations, it is possible to re-assess the tidal and wave energy of a region, which is true in the case of Scotland.

Dundee is the fourth largest city of Scotland. It also sits on the north Bank of the Firth of Tay which is on the eastern North Sea. The Orbital Marine Power have been awarded the contract for the main fabricating for the company´s first 02 tidal turbine. The Scottish based TEXO group are the ones who will be carrying out the working of the turbine on the quayside facilities of Dundee. [47]

The Orbital Marine power which is the developer for the floating tidal stream turbine will develop the 02 tidal turbine. The 02 will be capable of generating power over 2MW from the tidal resources. It is going to be considered to be the world's most powerful tidal turbine once it begins operating in the year 2020. [48]

The project is going to be financed via the EU Horizon 2020 funding and also a £7 million crowdfunding bond which the Orbital Marine Power had fortunately managed to raise at the beginning of the year 2019. Along with that, the project will also benefit from the Renewable Obligation.

Figure 32: Map of Dundee and the Firth of Tay alongside the North Sea [82]

The rotors of the turbine on the O2 could be turned about 180 degrees in order to be able to extract power from the tide during its inside and outside movement. The power generated from this project will be sufficient enough to be able to power more than 1,700 houses a year which has been said by the government.

The chief of Orbital had welcomed the funding provided by the government and made a statement on how this O2 project will be able to demonstrate about the emerging tidal industry and the ability it has to be able to create new jobs and also help open new doors to diversification for the growth in the supply chain of UK and moving one step closer for a zero carbon future.

10. The Purpose of the topics included

The main idea for this thesis is to help explain and discuss the extent and the socioeconomic issues which are involved in the evolution of TISEC in Dundee. In order to explain further, I have tried explaining the three questions in depth.

- The socioeconomic issues and the possible opportunities of TISEC creation in Dundee?
- The financial understanding of renewables and the socioeconomic issues?
- The needs of planning, legislation and policies needed for the TISEC industry?

In order to discuss, I have some particular elements regarding the TISEC evolution.

1) The expenditures
2) Financing and funding
3) The benefits of TISEC to the communities, regional and local.
4) The judging of policies and the stakeholder processes
5) The technologies involved, supply chain

10.1 Overview

The tidal industry or TISEC is said to be an emerging industry in Dundee. The tidal powerful turbine which is yet to be developed in Dundee does not contain a lot of information. There availability of data is low. Although, when we take a look at the energy developments from marine and oceans along with the other sources of renewable energy creations, the basic understanding of the socioeconomic issues can be understood.

The theory has been used to approach and provide the knowledge regarding the opportunities from the data available. The thesis helps understand the various socioeconomic viewpoints.

10.2 The Restrictions with the Information

Since the project is going to go under development, the availability of data regarding this is not much. There are reports in different languages but I was restricted to the ones in English. The TISEC industry is great in countries such as South Korea where English is not the common language. Therefore, due to the limitation of language, the usage of reports not in English have been kept out.

10.3 Results

The results from this thesis have been shown via examination of international TISEC socioeconomic researching and taking a look at the best practices available.

11. Research outside to Dundee

When we talk about the socioeconomic issues related to the evolution of TISEC industry abroad. There are circumstances to be taken into account. As discussed before, the main reason for this thesis is to break down and discuss about the socioeconomic proportions of TISEC into the following four points:

1) The technologies involved and supply chain
2) Policies and the stakeholder participation
3) The financial structuring and the funds
4) The benefits to the community

11.1 The Evolution of Technology

There are many projects undergoing construction or still in development all around the world. The TISEC industry and the technologies are still undergoing growth (RenewablesUK.2011). The EU is said to be at the lead of ocean energy. Their target is to meet at least 100 GW of a combination of wave and tidal energy by 2050.

The UK is said to be the leader in the wave and tidal energy, where the wave, tidal power revolution and its implementation spanning all the way from Cornwall to Shetland and goes beyond (HIE, 2016). The UK has the potential to supply up to 20% of its power from tidal and wave stream energies. When we take a look at the problems, we see that they are the reasons for hindrance. These challenges stop us from moving forward to help with technologies. There is not a lot of availability of sites and not a lot of access to finance. Also, grids can be an issue. On top of that, the crisis in the UK had led the investors to take a step back.

In order for the industry to improve, there is a requirement for a strong supply chain, workers with skills and also the need for investment. The need for promoting renewables should be the main motive for all. There could be a lot of connections made between industries.

11.2 The Grid Entry

The connectivity to the grid is a very complex issue for the development of TISEC. The costs for the connections of the grid can be extensive due to the high costs of the radial lines which could go up to a lot of kilometres. The need to reduce the costs of these cables, along with the need to creating less complex grid connections is vital (Colander & Monroe, 2011).

The difficulties of the grid infrastructure and the capacity of the UK is based on centralised generation units. The delays which have been with the investments and the approval of new upgrades which have been a hindrance to the remote nature of the generation from renewable energy (Renewable UK, 2017).

11.3 The Test Site Connection's.

The TISEC industry which is undergoing a lot of demonstrations and developments. The possibility to be able to test the technology present in a possible condition takes the whole process one step further to help continue the development of TISEC to advancement. It is important to be able to monitor the working of the tidal devices which have been deployed into the water. This is the basic necessity. (Dalton et al. 2009; SQWenergy,2010).

The approval by the government for the test sites to be used is vital. The government is responsible for the funding and the following should be given approval to:

1) The impact on the Environment assessment (EIA)
2) The free cable connections
3) The data collection for free
4) Acceptance site with the license

There are plenty of test sites for the tidal and ocean energy which have been developed. Some examples are as following:

Wave Hub has been under helping evolve projects since the year of its first deployment in the year 2010 in Hayle. The explicit target being to bring forward new solutions and growth to the sector of marine energy in UK under the Regional Development Agency. They plan to become the agitators in the implementation and responsible for the marine energy devices. There was a project made by the Ocean Power Technologies to create a power buoy array with power up to 5MW. [61]

The European Marine Energy Centre (EMEC) were founded in the year 2003. With Orkney Islands being the base due to its richness in oceanic energy Their contribution to the field of marine energy has brought forward a lot of investments in this field. Along with that, they offer research work. Also, they have been the forerunners in the implementation of converters around the globe. [62]

BIMEP Spain also the Biscay Marine Energy Platform test site is said to be located off the coast near the village of Armintza which is in the Basque country. The Wave Energy Converters had placed the Basque country at the forefront of marine energy and developed a technological cluster revolving around the industry. They are vastly sued for the proofing of the devices since the year 2011. [61]

Nissum Bredning testing field was created in Denmark in the year 1998 under the authority of Wave Energy Association. With the years ahead, they underwent management, direction in the field of research of wave energy evolution. The testing field exist in the northwest of Jutland. They have created many different types of wave devices which could account up to at least 30 types. [62]

11.4 Supply Chain Development

In general. The costs for production and agreements for wave and tidal industries are high. The main reason being due to the size of the firms being small and not having a lot of access to the manufacturing resources needed. Along with that, they face an issue with the complexity of the technology (Levdal & Aspelund, 2011; 2013) There is an increase in the costs for the production in house where the solutions seem most preferable to the market.

There are a few reasons for the cost being so high:

1) The existence of it in a pre-commercial phase for more than a decade.
2) The plausibility is restricted.
3) There is also a lack of designs which has led to the development of other technologies.
4) The size and the weight and also the difficulties of the technologies involved with this industry do not leave a lot of options in the market.

The table below consists of the characteristic of the seven companies who had been in the development status in 2014.

Case firm	Founded	Number of employees (2013)	Technology	Country	Full-scale unit	Product development status (2014)
Floating Power Plant	2004	< 20	Hybrid wind and wave	Denmark	6 + 6 MW 1,800 tonnes 80 meters	Continuous ocean tests of a 1:2 scale device (37 m wide, weighing 320 tons) since 2008. Grid connected since 2012.
Flumill	2002	< 20	Tidal	Norway	2,1 MW 160 tonnes 18 x 48 meters	Development of a full-scale demonstration plant with two to four devices.
Langlee	2006	< 10	Wave	Norway	50 kW 70 tonnes 15 x 15 meters	Full-scale ocean testing is planned in the Canary Islands in 2015.
Minesto	2007	< 30	Tidal	Sweden	0,5 MW 7 tonnes 12 meters (wing)	A 1:4 scale pilot has been tested in the waters of Northern Ireland since 2012.
Pelamis	1998	< 50	Wave	UK	750 kW 1350 tonnes 180 meters	Has built and tested six full-scale units.
Seabased	2001	< 30	Wave	Sweden	100 kW 12 tonnes 4 meters (buoy)	Has manufactured the first 42 units (25 kW) of a 10 MW park, which is scheduled to begin operation in 2015.
Wello	2008	< 10	Wave	Finland	0,5 MW 220 tonnes 30 meters	Has since 2012 been testing a full-scale, grid-connected prototype in the Orkney Islands.

Table 5: Characteristic of seven companies [63]

Segments of the Supply chain

The supply chain segmentation is obtained from various reports and then assessed from a list of 10 key segments:

Supply Chain Segment	Description
Technology developers	Marine energy conversion device innovators, designers and developers.
Manufacturers and suppliers	Manufacturers and component suppliers.
Project developers	Utilities and independent power producers.
Development services	Resource assessment/modelling, mapping, environmental impact assessment, sea floor environmental assessment and related marine safety and supply consults, permitting, approvals planning, marine corrosion consulting.
Supporting technology providers	Wave/tidal current resource measurement devices, environmental monitoring devices, buoys, underwater remote vehicle operators/owners, technical resource monitoring and data collection.
Engineering and construction	Safety management, work platforms, underwater operators, cabling and electrical interconnect for marine operations/facilities, anchoring systems, engineering firms (electrical, civil, mechanical), on-site supervision and management.
Operations and maintenance	Operational monitoring, transportation, port facilities and marine operators with related experience (including transport vessels and operators and certified diving teams) with the ability to do deployment/removal, emergency repair, mitigation strategies and asset management.
Research and development	Academia, private and public research centres and bodies.
Policy and industry support	Government policy development, industry associations and non-governmental organizations.
Business services	Legal, financial, insurance, business, communications, market research and training activities.

Table 6: Supply chain segments [83]

11.5 Gaps and Possibilities

There are various sectors of strength, frailty and unknowns to the supply chain segmentation. The table below recognizes them in table above and summarizes below:

Supply Chain Segment	Gaps
Technology developers	Marine energy conversion technologies need to be reliable, efficient and cost-competitive in comparison to other renewables in order to provide an opportunity for a commercial industry to flourish.
Manufacturers and suppliers	A Scottish supply chain study found that most marine energy technology developers want to assemble their devices using proven, reliable, 'off-the-shelf' subcomponents purchased from established suppliers. [2] Identification and design of subcomponents that are not already available but will complement Canada's strengths may provide opportunities for manufacturers and suppliers in Canada.
Project developers	As marine energy technologies advance towards commercialization, risk will decrease and projects will become more financeable, allowing independent power producers and utilities to become more active in the sector; however, policy and incentives are also required in order to engage project developers.
Development services	Considered to be well serviced, with several companies developing experience nationally and internationally with wave and tidal energy activities.
Supporting technology providers	Considered to be well serviced.
Engineering and construction	A number of engineering firms are becoming engaged as opportunities arise. It is critical for Canadian engineering firms to become involved early as the use of Canadian engineering greatly increases the likelihood of supply from Canadian companies.
Operations and maintenance	Deployment, operations, maintenance and retrieval technologies and procedures may be necessary to manage wider weather windows as well as more extreme environmental conditions.
Research and development	More research is needed to address the full spectrum of issues at this stage, from technology and environmental to full-systems considerations.

Table 7: The gaps recognized based on the segments of supply chain. [84]

11.6 Policy Framework and Stakeholder Participation

The processes related to the policies and the stakeholder participation to the tidal industry are described in the section below. The TISEC industry has been in development since the past few decades and is improving though being undeveloped and not so consistent. There are many policies existing on all the marine energy resources.

Policy

With the rapid development in the research of renewables from marine energy, the governments from several countries have made the introduction of policies to support with the evolution of the projects and later the implementation of OE projects (AEA Energy & Environment, 2006). As mentioned before, the lack of legislations in particular to tidal projects.

The need for simplifying these technologies on a daily basis will require a lot of guidance and adequate amount of experience to help promote the development in respect to the risks involved.

There are many different policies and UK lead in the advancement of Marine energy and the policies related to it. They have moved rapidly in the past years and still pushing for the evolution of TISEC industry in the years to come.

The United Kingdom and Scotland

The **Marine Energy Array Demonstrator (MEAD)** was a scheme of £20m capital grant fund which was given by the DECC to help support the two projects involving the testing of array devices. The process was closed in the June of 2012 with awards made in 2013.

The Scottish Government's **Marine Renewables Commercialisation Fund (MRCF)** had supported with £18m carbon trust to support two projects for the profit-oriented scale array devices in the Scottish waters [67].

In the year of 2013 the **Crown Estate** had invested around £20m in two wave and tidal array projects with a capacity of up to 3MW.

The **Renewable Energy Investment Fund (REIF)** by the Scottish Government has made the availability of loans, equity and guarantees of up to £103m to projects to help promote the growth of marine energy in the Scotland. [67]

Such as the new tidal turbine has been given to the orbital powers by the Scottish government, the **Saltire Prize** was made by the Scottish Government, which is a £10m fund which is awarded to the owners of a tidal or commercial project in the Scottish waters that tends to produce a lot of power [66].

The Energy Technologies Institute has made a lot of investments in the marine sector and TISEC industry. They also make assessments of the wave and tidal array systems. Also, the Reliable Data Acquisition Platform for Tidal (ReDAPT) was a project that helped with installations of 1MW tidal generator in 2013 at EMEC.

Portugal

Investments in the field of marine energy has been significant by Portugal since the year 2000. They understand the need to promote renewables and have taken steps to do so. There have been quite a lot of investments made in Portugal for the development of renewable technologies since 2000 and especially in the marine energy sector.

In the year of 2007, the formation of a wave energy pilot and demonstration zone was created. It was an energy pilot zone of 320 km^2. They had announced that these zones would be used for the deployment of 80 MW and 250 MW in the first and second phase. Due to the large size of the plot, this was highly innovative This had shown that the expectation of wave energy in Portugal [69].

The FIT is defined by the law. And is said to be around 25cEUR/kWh from start and going down to 16-18cEUR/kWh during the pre-commercial phase and then eventually to 10cEUR/kWh in the commercial phase [68].

Germany

Germany has constantly been adding to the renewable sector. In the year 208 they made the Coalition agreement to meet the targets for renewable energy.

The main power generation in Germany is from offshore wind. The Offshore Wind Energy Act of 2017 was used to define the incentives on market based for the members of the power industries [70].

The Federal Maritime and Hydrographic Agency (BSH) had supervised the licensing for the renewable energy projects in the EEZ based on the Maritime Spatial plan for the North Sea.

The Table below shows a list of Tidal Energy Policies:

Country	Tidal energy targets	Ocean energy feed-in tariff (FIT)	Open sea testing centre	Research, Development & Demonstration support
France	380 MW by 2020	FIT of EUR 150/MWh	2 test sites for tidal energy	Financial support for five demonstration projects
Germany		Tidal power covered under EEG[a]		Research programme for next generation maritime technologies
Ireland	Explicit target in NREAP[b]	Planned FIT of EUR 0.28/kWh	1 operational, 1 under development	R&D budget for tidal energy
Italy	Explicit target in NREAP			
Japan				Ocean energy technological research and development project
New Zealand			1 planned	Marine Energy Deployment Fund (2007-2011)
Portugal	Explicit target in NREAP	FIT halted	1 planned	
South Korea	Specific targets in renewable energy plan	Ocean under RPS[c]		Large and growing R&D fund for tidal power
Spain	Explicit target in NREAP	FIT suspended in 2012	1 operational 1 planned	National and state funding available
Sweden			3 operational	
UK	Explicit target in NREAP	Tidal projects covered under ROC[d] scheme	3 operational, 1 planned	Commercialisation and investment funds; Demonstration scheme;
USA		Eligible for Clean Renewable Energy Bonds and Renewable Electricity Production Tax Credits	2 operational, 1 planned	Grants available for companies

Table 8: Policies showing about different countries. [71]

Country	Tidal energy targets	Ocean energy feed-in tariff (FIT)	Open sea testing centre	Research, Development & Demonstration support
Australia				Support for demonstration projects
Belgium		Eligible for green certificate scheme	1 operational	
Brazil				R&D programme for ocean energy
Canada	Marine Renewable Energy Technology Roadmap	Community FIT for tidal power	2 operational	CAD 4 million, Marine Renewable Energy Enabling Measures Programme
Chile		Special FiT being developed	1 planned	
China	National Ocean Technology Centre (NOTC) is developing 2030 strategic report	Specific FiT for ocean energy	1 under development	Special funding programme for ocean energy (SFPMRE); Establishment of Administrative Centre for Marine Renewable Energy (ACMRE)
Denmark		FIT of EUR 80/MWh (uniform across all renewables)	1 operational	EUR 3.4 million for wave projects 2014-2015
European Commission (EC)	Strategic Initiative for Ocean Energy			NRE300 programme;

Table 9: Policies for Tidal Energy based on different countries [71]

European Commission

There are several different directives which have affected the growth, monitoring and processes of ocean energy projects. The deployment, monitoring has been the responsibility of each EU Member States.

The **Renewable Energy Directive** was used for the promotion of the usage of energy from the sources of renewable energy. The main objective being to produce 20% of energy from renewables by the year 2020. Along with many other Renewable Energy Directives a lot of

Member states have been persuaded to take action for the evolution of wave energy and TISEC industry.

The **Maritime Spatial Planning (MSP)** is a see-through process which includes all the involvements from stakeholders with the objectives being to help plan where and when the human related activities will be taking place at the oceans. In the year of 2014, the EU parliament and the council of EU embraced a new Directive to help create **(Directive 2014/89/EU).** With the Directive having four bases which are related to the fishermen's, the transportation in marine industry, environment related and energy. [70]

11.7 Stakeholder Participation

To help alleviate the change in climate to help improve the stability economically along with the national security, renewable energy is a key solution to help tackle some of the most problematic social and environmental complications. (El Bassam 2001; Elliott 2000).

The inputs that we take in from the stakeholders re deemed critical in the arenas such as renewable energy (Conway et al. 2010; Portman 2009). The need to be able to transform the energy strategy away from the ones that are imported such as fossil fuels and non-renewable fuels to renewable energy evolution is dubious to happen without the participation of a high-level stakeholder. The engagement. The engagement of a stakeholder is described as a process where organizations, people, communities take up a role in taking up decisions affecting them. The benefits from the participation of a stakeholder being environmental decision making (Reed 2008), such as building up trust, acceptance, helping enhance the attributes of decisions, transparency and accountability. It is evident that when people are not taken into consideration and not informed about the processes and decisions, they will oppose the end result [65]. Social learning is something that can be encouraged by stakeholder participation (Blackstock et al. 2007). The Dimensions can be broadened, problems can be solved and in specific, the information not considered to be technical by non-scientists to enter the decision-making process (Glicken 2000).

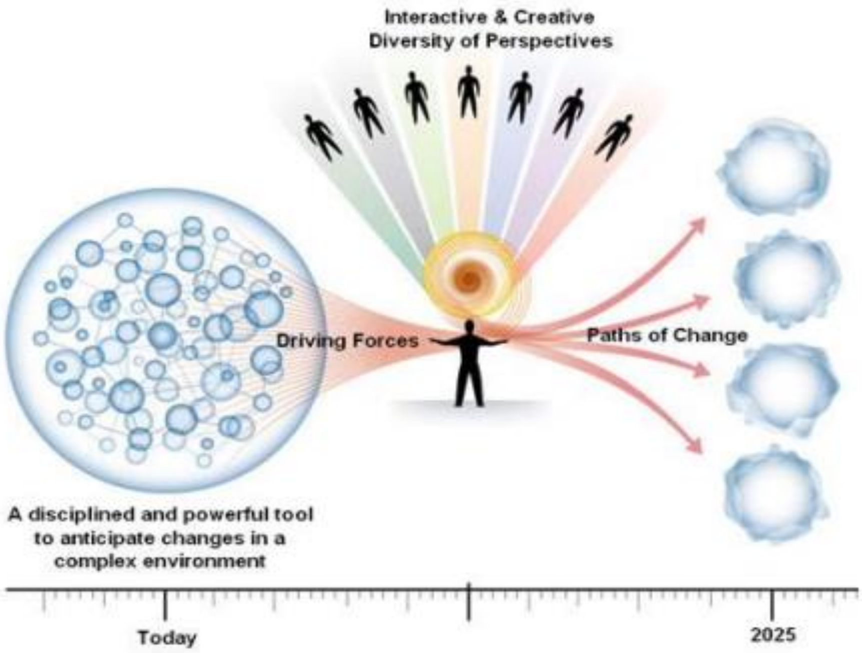


Figure 33: Analysing the conceptual model and the problems driving forces recognized [64]

In reality, the engagement by stakeholders could not meet the represented claims (Reed 2008). The inputs which are incorporated from several and multiple stakeholders to help make decisions is challenging (Glicken 2000). It requires understanding at a high level. The value of participation by stakeholders has to be at a suitable moment and in a way such that it helps them to successfully shape decisions (Reed 2008).

The steps used to design a successful participation of a stakeholder is to design it first. There are many definitions of stakeholder in terms of business but the most common feature being they are the ones needed to help recognize and determine groups which are related to a particular problem (Glicken 2000). The decisions made by the stakeholders affect everyone involved in the process. The involvement is critical in the process of tackling a challenge and the identification of stakeholder is very much relevant to plan the participation of stakeholders. (Bryson 2004).

The common body of the Tidal energy stakeholders include developers, suppliers, people and the government. The table below depicts the stakeholders who are involved in the stakeholder participation according to the British Wind Energy Association (BWEA).

Statutory consultees	Stakeholder planning	Community stakeholders	Coactive stakeholders
- Department of Trade and Industry. - Department for the Environment and Rural Affairs. - Department of Transportation, Regions and the Local Government. - Departments of Sports and Media. - Civil Aviation Authority. - The Country side agency. - The local communities. - The national inheritance and Nature. - National Parks. - Ministry of Defence. - The Maritime Agencies.	- The National Fishermen's Organisations. - Investors. - The Wildlife trusts. - National trust. - Marine and Ocean Interests. - The Marine prevention society. - Ramblers Association - Trade unions. - Universities. - The project developers. - Green peace. - Surfers against Garbage. - The foundation of Surfriders.	- Zonal or the local fishermen alliance. - Community councils. - Groups believing in presence of Gods. - The residents present. - Residents Associations. - Sailing clubs. - The local fishermen's association. - Women's communities. - Touristic agencies.	- The wind industry supply chain. - Offshore oil industries. - The grid owners of electricity - Offshore wind industries providing energy

Table 10: Types of stakeholders on national and regional levels (EquiMar, 2011c).

12. Efficient agreeing and Environment Procedures

There are many states which have made dedication towards these sectors and have tried making the complex process simpler by consenting to the environment procedures which include:

1) Tailored and acceptable processes for licensing.
2) Just one shops for the smooth running and making the process of consenting rapid.
3) Flexibility
4) The collection of data corresponding to the size of the project and also how it affects the environment
5) The sharing of the collected data amongst the sites and the technologies where they can be applied. [72]

Case study on Rochdale

Lewis 40 MW Wave efficient, Aquamarine Power, in Scotland

Helping make the consent flexible.

The Aquamarine power had been granted full agreement to its 40MW project off the north-western coast of Scotland in the year 2013. It was during the month of May that Scotland had agreed that the project would be based on to deploy around 40-50 Oyster devices and in return provide electricity to up to 30,000 homes.

During the period that the consent had emerged, the device which was an Oyster 800 for still undergoing tests in EMEC. This meant that Aquamarine could still change some designs and implement the necessary changes required before the installation on the Lewis farm.

12.1 Socioeconomic Influence of TISEC Evolution

The sustainability involving the tidal energy in general is self-conscious by the aspects of economic, environmental and the issues revolving around the society. The impacts are still far from having been implemented completely. The impacts still have to be assessed and the affects have to be taken into consideration. The research involving the socioeconomic impacts needs to take into account on how to create the industry sustainably, stabilizing the needs for the society and the communities and making sure of not harming the environment. There are not just positive impacts when it comes to the TISEC development. Hence, it is important to address the positive and the negative impacts it has on the local communities as well. The field data are difficult and costly to obtain.

There are not many projects around the world. With the ones existing present in China, UK, US, Ireland Korea and Canada. The questions that strike the people wanting to invest or know about the TISEC technology is what will be the benefits revolving around it. How prosperous could this industry be when it comes to supplying energy I the field of renewables. Also, what are the socioeconomic benefits from this technology. [60]

12.2 The Expenditure for TISEC

Compared to the other sources of energy, the energy from the oceans tend to have a higher capital financing needed. (such as the costs of installing the devices in the water) on the other hand having low payment costs for the fuel and maintenance. In order for the projects to be triumphant in the coming future, the investments being made have to be paid off by the capacity produced. The lower costs than the carbon sector will be advantageous. The LCOE of the energy from those of fossil fuels will tend to be lower than that of the energy from the ocean for a considerable amount of time. However, this would depend much on the CAPEX/OPEX ratio of that from the energy from the ocean, which seems to be promising due to the money being invested will generate continuing value. [51}

The new technologies will always be considered to be riskier than the ones which have already been established. On the other hand, the reward from the new ones being higher. The Ocean Energy Strategic Roadmap had helped create a system that enables the project developers and the manufacturers of the devices to help crossover the gap on uncovered risk. The main idea being to reach the target of 27 % renewable energy by the year 2030.

Under some positive scenarios, the 4 GW cumulative capacity in the year 2030 will accumulate to a cost of 13 billion EUR in European Projects.

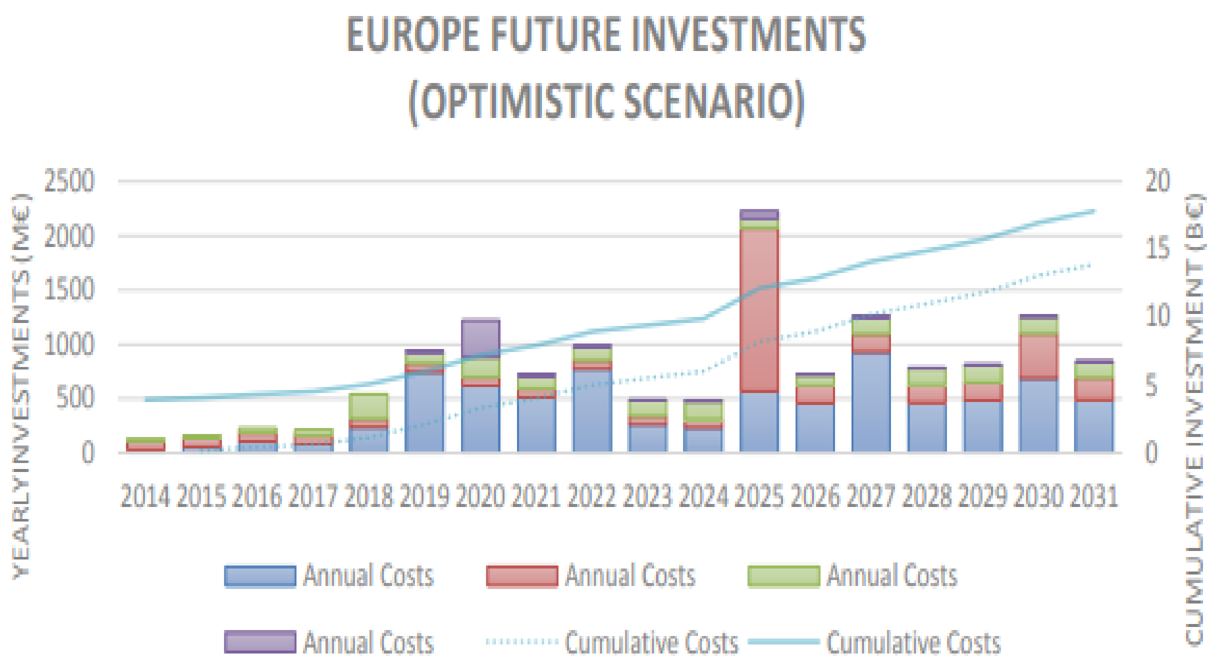


Figure 34: The investments to be made in the future [51]

The breakdown of the different types of technology financially has been shown below:

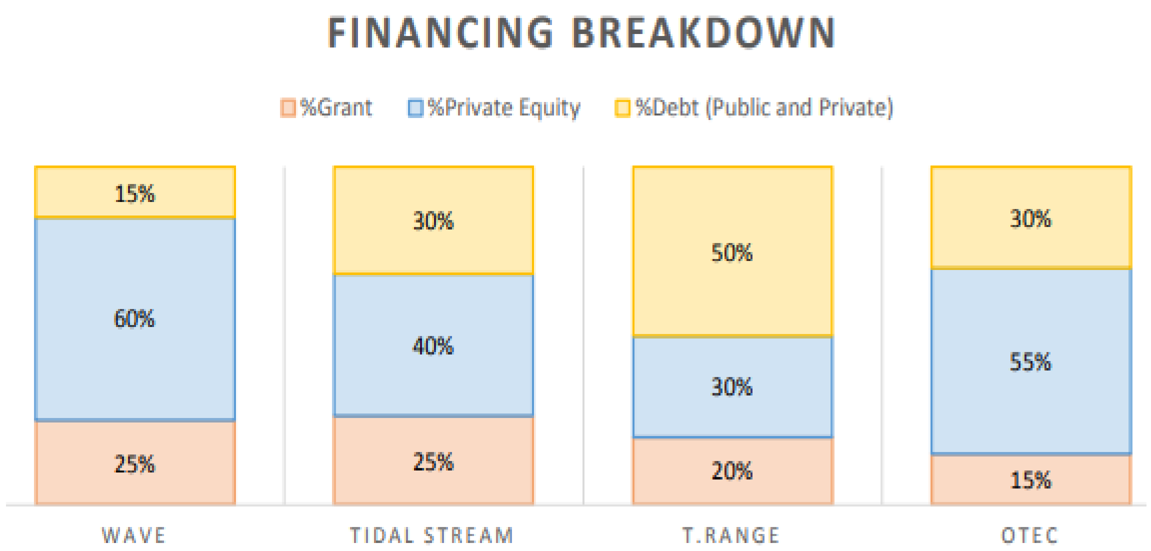


Figure 35 – The expenditure list based on technology [53]

Projects which have been developed over the world from the beginning of 1978 until now. There was a report by Ocean Energy [51] which states that more than 6 billion euros has been permeated into these projects. Along with that, more than 2 billion euros has said to be administered into developing these new technologies. These projects could have a strong conduit of around 1GW. [53]

Additionally, the decade to come could see the installed capacity reach up to 4GW and the expenditure needs to reach 9.5 billion euros.

The technology will generate more investments coming via private loans. The requirement for public funding which would attach private capitals and the payment research would recoil to one fourth of the investments being made in total [53].

Figure 36: Investments made till date in Europe [53]

Present costs

The overall costs depend highly on the different types and number of machines that are being deployed and created. Most of these costs are generated from large scale prototypes. When it comes to creating them in real life, the capital costs increased fourfold than that of the ones from building the prototype.

O&M costs

The costs from the operations and management of the marine renewables arise from various parts which incorporate: maintenance which could be planned or unplanned, licences involved, insurance which authorize the devices to be stationed and take into consideration the risks involved. There is continuous monitoring of the wave and tidal conditions which is viewed by the device action.

The figure below depicts the capital costs originated from the tidal current farms as well as the maintenance costs involved. It is considerably hard to anticipate the costs which could be generated due to not having much of experience but given that we have information about many offshore windfarms, it can be estimated. [56]

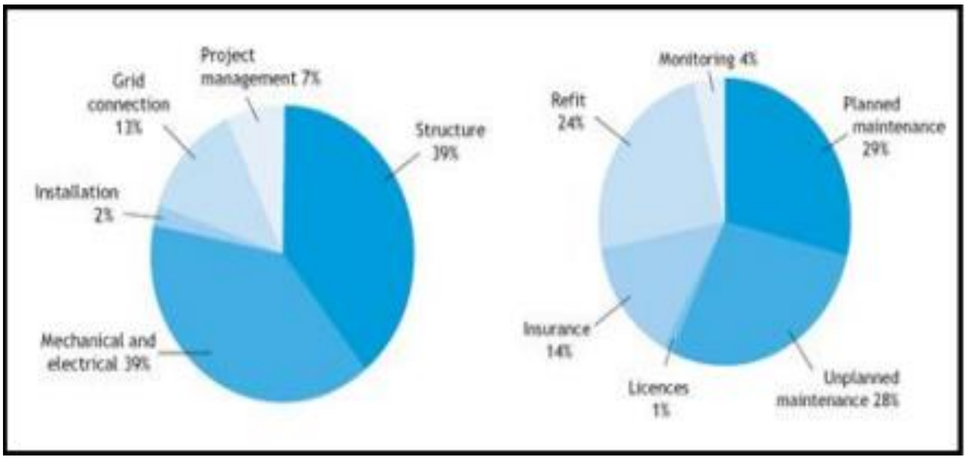


Figure 37: Breakdown of the O&M costs from tidal stream farm [56]

12.3 The roadmap

As we spoke previously about tidal range is one of the most developed technology. The maturity of the technology is being obstructed by the high initial costs and the effects it has on the environment. On the other hand, tidal power will be a developed technology. Implementations of these technologies have already been made and are in working condition. Although, they are small in size, they could be joined all together to increase the size. The table shown below described about the juxtaposition of different sources of marine energy.

	Tidal range	Tidal stream	Wave	OTEC	Osmosis: PRO
Maturity	Commercial	**Pilot/ Demonstration**	**Pilot/ Demonstration**	Pilot	Lab
Potential (TWh/y)	200 to 380	300 to 800	500 to 4 000	10 000	1 600 to 2 000
Interesting locations	Localized spots with favorable topography	Localized spots distributed around the world	Along the coast line in high and low latitudes	Around the Equator	Main estuaries
Main limitation	Large investment cost and environmental impacts	Maturity, grid and cost (government policies)	Maturity, grid and cost (government policies)	Large investment cost	Low performance of the membrane
Investment	3.8 to 4.2 M€/MW	**2015: 4 to 5 M€/MW 2020: 3.5 M€/MW**	**2015: 4 to 5 M€/MW 2030: 2.5 M€/MW**	2015: 20 M€/MW 2025: 10 M€/MW	NA
Production cost	230 €/MWh	**2015: 200 to 250€/MWh 2020:150 €/MWh**	**2015: 200 to 250 €/MWh 2030:<100 €/MWh**	2015: 400 €/MWh 2025: 250 €/MWh	2020: 50-100 €/MWh
Market targets	Large power plant	Farm (Association of various units)	Farm (Association of various units)	Large power plant	Large power plant

Figure 38 Comparison of the various marine sources of energy (Statkraft; Paillard, Lacroix, & Lamblin, 2009; Ifremer, 2011; IEA-Energy Technology Network, 2010)

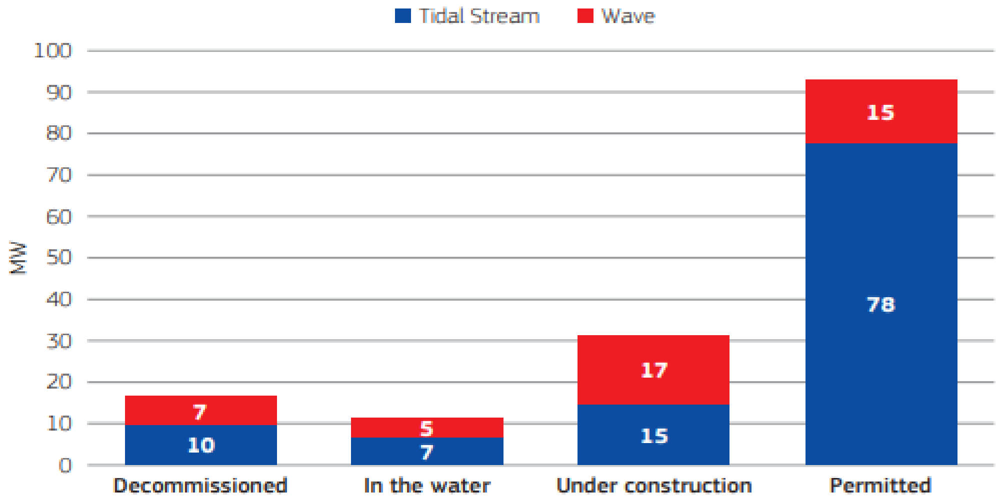


Figure 39: The deployed tidal stream and the capacity of waves under construction [85]

Europe will be the centre of attraction for the most of the developments and according to a report in 2016 it shows the tidal stream and the wave capacities which were under construction and the permitted capacity (MW)

The development for tidal energy will be continuously developing in the coming years.

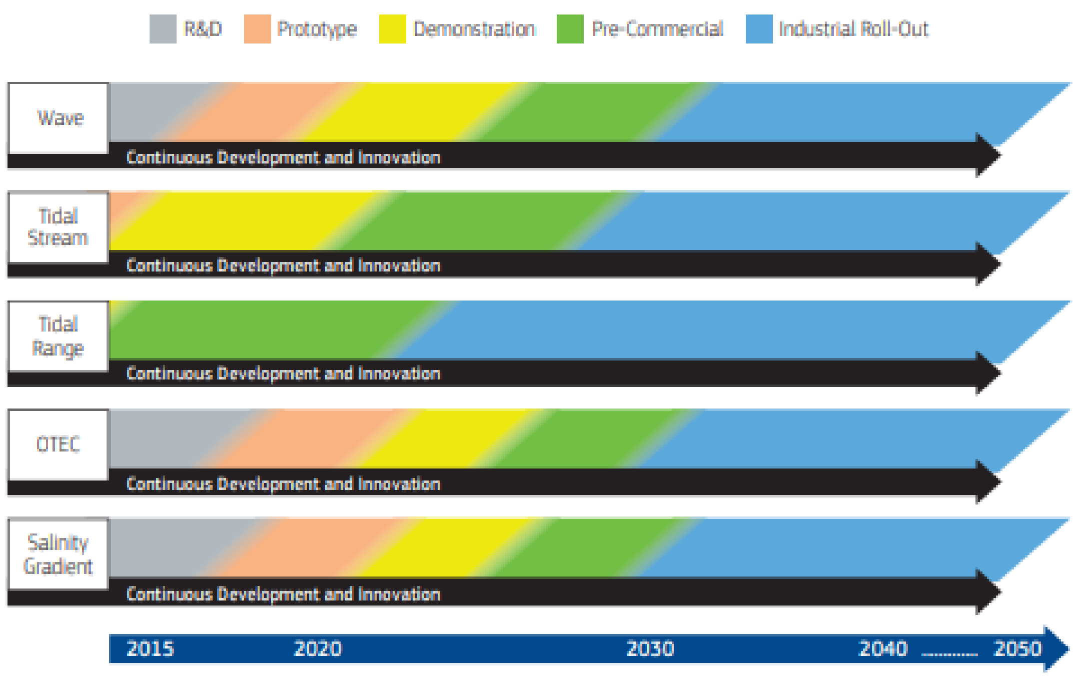


Figure 40: Showing the development phase of ocean technologies. [86]

13. Benefits to the community and trends

As we know the energy obtained from renewable energy is cheaper than any other form of energy existing in the world. Along with it being cheaper, it brings along other factors such as economic and the benefits to the society.

An economic benefit which does not come much into the spotlight is the economic benefit. Renewable energy can be expanded in areas with little or no electricity. It is not easy to be able to obtain the required resources for the generation of electricity from renewable energy resources. The most important factor being the infrastructure and the costs involved. The local governments are the ones who should lead by example by helping produce electricity on site, along with the purchasing of energy from renewable sources.

13.1 The Ocean Energy Technology Readiness

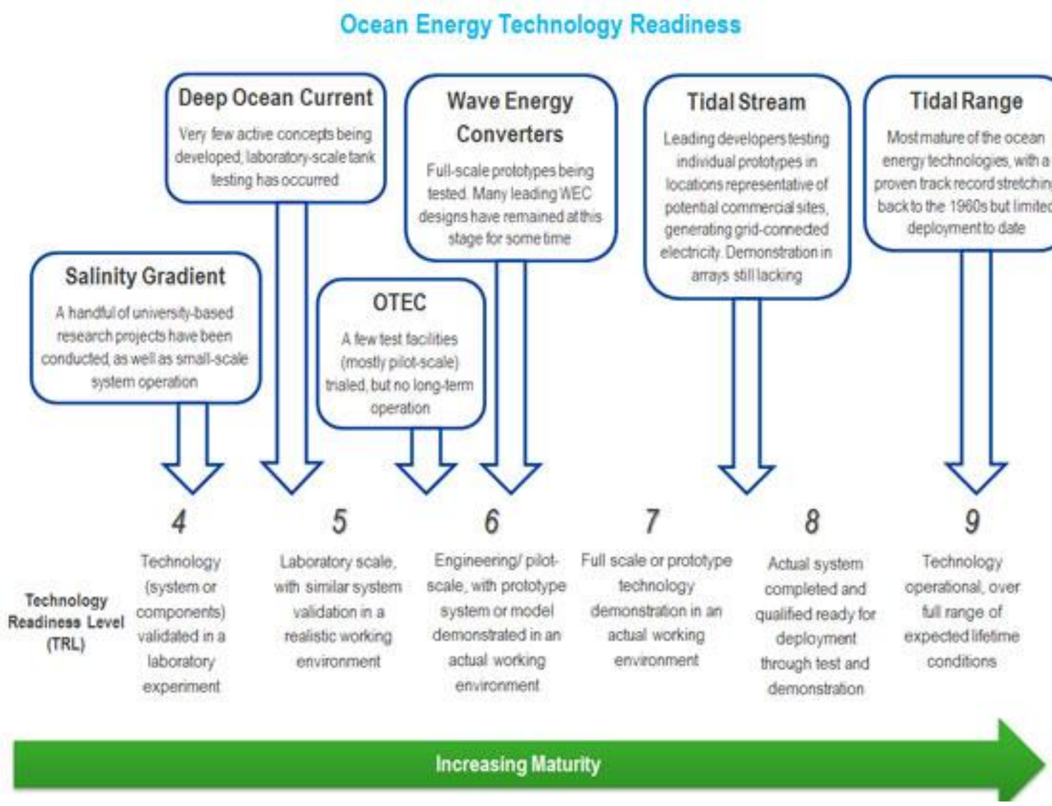


Figure 41: The state of Ocean energy [54]

14. Some basic benefits of Renewable energy

1) Energy that is generated which produces no greenhouse gas emissions from the fossil fuels helps reduce various forms of air pollution.

2) With the help of renewable energy resources, our dependence on fossil fuels reduces along with the need for importing fuel.

3) This helps improve the economic development in certain aspects and fields along with creating more jobs. [54]

Economic Refreshment

It is very much obvious that renewable energy does not just make contributions to reduce pollution but also increase the economic status. According to a report by IRENA, says that by "Doubling the share of the sources of renewables in the global mix of energy by 2030 would see an improvement in the GDP by around 1.1 % or around 1.3 trillion USD.

Another important solution is which shows how the investment in energy can profit the impact trade. From the importing of fossil fuels switching to renewables has a favourable trade implication. The reduction in importing of fossil fuels can help bring the balance to trade by improving it and also gain the GDP. The EU33 surpasses its net exports to around 15 USD billion along with the share of the renewables being said to be doubled to USD 21 billion. [58]

Recommendations

In order to establish a renewable energy community, via public and private relationships or the public companies. There is also a lot of scope to support the communities to help set up common energy framework for the regional authorities. By providing awareness, advice and financing can be perceived with ease and followed through.

Raising Awareness

1) The policy makers on a regional level could be the ones leading the way in spreading the information and carrying forward the communication about the benefits which arise from that of community energy. This does not mean informing just about the economic benefits for the ones who want to get involved but also the challenges from the society which could be bettered.

2) There can be assessments made by the regions to help start the process on renewable energy opportunity. They could explain about the money which would be invested in renewable energy resources would bring back a return. To do this the assessment should also represent a mapping of all the stakeholders along with the ones who have the legal capacity to help improve the community energy evolution.

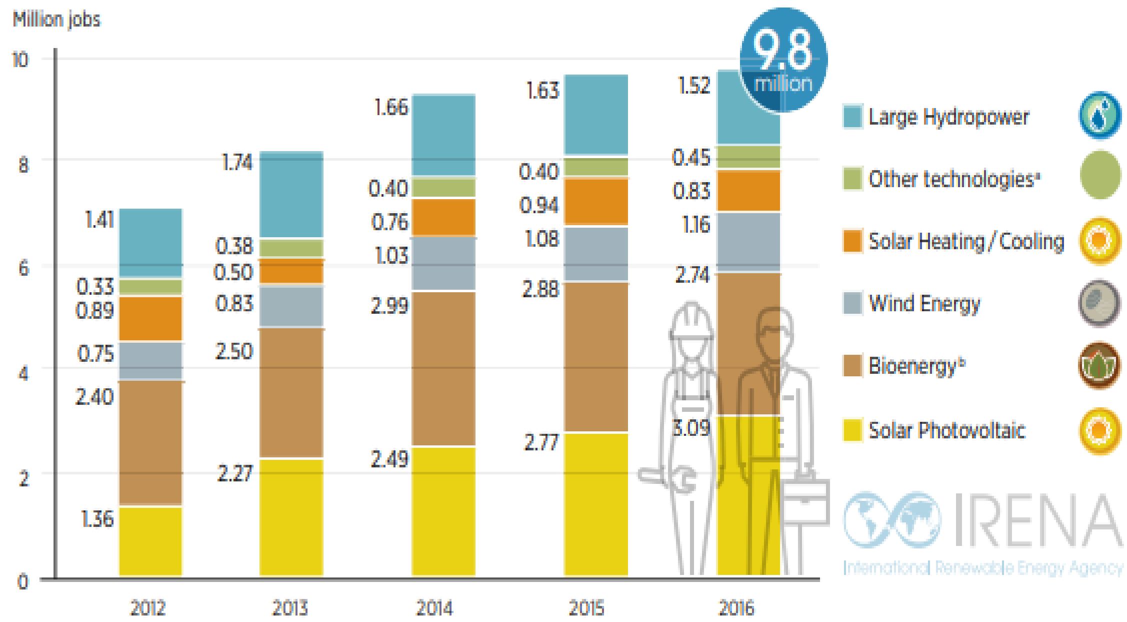
3) The energy agencies existing along with the big investors could be instructed by the public authorities to set up a platform which would congregate the people to explain them about the community energy. This would create an interaction between them and steps could be taken to help improve the system. [55]

Employment and jobs with the technology

According to the year 2016 which stated that around 3,1 million jobs existed in the sector of renewable energy**.** With solar PV having implemented the most and grown by 13% in the year 2016 and has grown by almost 3 times since the year 201 which will be depicted in the figure below.

The sector of liquid biofuel has seen a reduction and growing slower at only a 3%, whereas the wind industry booming and will develop by 8& and create around 1.2 million jobs. [57]

According to the report on IRENA, the "leveraging Local Capacity for Solar PV" inspected the patterns and the necessary skills which would be required for an architected 50 MW solar PV project. More than 250,000 people would be required.



Source: IRENA, 2017b.

Figure 42: The development in the renewable energy employment globally during 2012-2016 [87]

15. Opportunities and Barriers

With the creation of the Tidal turbine in Dundee Scotland will see a lot of vital characteristics like the Feed-in-Tariff and the Strategic Environmental inspections in place.

The table below depict some of the advantages and the barriers in Dundee which could hamper with the development in Dundee.

Opportunities	Barriers
According to the government which has shown their full support to the tidal turbine being constructed: 1) The support to the communities who would require a better level of understanding about the technical, monetary and the regulatory required to help create these projects 2) A total of 10 £ is available for the projects which would be • Related to the capital costs in order to create a material/ new innovation which will be directed towards reducing the cost of tidal energy • They would be depicting the needed for and will be putting on worth to the Sottish Government support • They should be deployed in the Scottish waters before the March 2020 • Along with having an economic impact on Scotland, they should be showing a potential and social impact as well which would create an alliance with the Scottish supply chain 3) The FIT which will be provided for the development of the tidal turbine.	1) Dundee is not a small place to build a project in and hence could be challenging given the time schedule. 2) The real challenge lies in order to help find the initial costs for the development of TISEC projects. 3) Though the government is showing their full commitment to the cause, but the disputes inside and outside the government can take much more time and effort. 4) Lack of data 5) With the Texo Group having the contract there will be more difficulties for the old people and the ones who do not have the required skills to obtain the job. 6) The required cables, converters is not very much easy to obtain throughout Dundee.

4) They are planning to create a test centre which will be worth 2£ for further developing the marine renewable energy in Dundee. [59] 5) The COMFIR had made a commitment to generate around 25% of Europe's wind and tidal power by 2020. 6) The wind, wave and tidal power could show around 60£ billion worth expenditures and create more than 60,000 new jobs. 7) Texo Group will be contracted for the construction and create new workforce.	

Table 11: The opportunities and barriers.

16. Budget of the project

Regarding the economic assessment, the following table shows the spending, the expenditures per hour and also the total cost of the thesis.

	Hours (h)	Cost per hour (€/h)	Final Cost (€)
Laptop	-	-	750
Phone along with internet (6 months)	-	-	160
Utilization of light (6 months)	-	-	120
Microsoft Office license	-	-	180
Home Material	-	-	200
Total without VAT	1410 €		
Final with VAT (20 %)	1692 €		

Table 12: Project final budget

17. Environmental Impact of doing the project

In the section below I have added information regarding the impact this thesis and research work has had on the environment.

Most of the work has simply been done on the laptop regarding the research work and drafting of the thesis. The usage of my phone to be in touch with some friends and colleagues who have worked or working in similar fields of engineering has consumed some energy. The guidance and support I had been receiving from the professor Eduard Egusquiza Estevez and all the information has been the subordinate purpose of the computer.

Along with that, the usage of paper, electricity, heating and ventilation have also been taken a note of.

The table below will depict all the energy used and the carbon dioxide proffering:

	Power (KW)	Hours (h)	Energy (KWh)	$C0_2$(Kg) [0.364 kg $C0_2$/KWh]
Laptop	0,05	418	20,9	7,60
Lighting	0,5	526	263	95,732
Phone	0,005	4	0,02	0,0728
Heating	1,5	35	52,5	19,11
Airing	0,03	284	8,52	3,10
``Total	2,085	1,267	345	125,61

Table 13: Environmental Impact

18. Work Plan

The table below represents the organization of the work and how the whole project took place:

Venture	Beginning	Time Span	Realization
Understanding of the turbines and tidal industry	11/11/2019	12	14/11/2019
Documentation regarding the turbine	16/11/2019	8	20/11/2019
Gathering of Information about tidal energy & wave energy	23/11/2019	18	29/11/2019
Understanding the future prospects	2/12/2019	16	4/12/2019
Documentation regarding the future prospects	5/12/2019	24	11/12/2019
Understanding of physical principles of TISEC	21/12/2019	38	2/1/2020
Information Gathering of the tidal deployment	6/1/2020	15	13/1/2020
Challenges about the study	16/1/2020	20	22/1/2020
Understanding of the opportunities and barriers	27/1/2020	11	30/1/2020
Documentation of finances and funding	4/2/2020	18	13/2/2020
Understanding of the stakeholder participation	15/2/2020	6	19/2/2020
Documentation about regarding the policies	25/2/2020	20	3/3/2020
O&M cost and R&D in the marine industry	4/3/2020	32	9/3/2020
Documentation about Dundee and Orbital	11/3/2020	35	14/3/2020
Understanding the TISEC industry in UK and the world	16/3/2020	9	19/3/2020
Assessment of the activities	19/3/2020	31	29/3/2020
Report writing	14/3/2020	44	19/4/2020

Table 14: Work Breakdown

19. Conclusions

With this thesis I have discussed about the socioeconomic issues and the possibilities of TISEC in Dundee and the world.

Tidal energy is a clean renewable source of energy. The harnessing of the kinetic energy which is enveloped in the tidal streams is appearing to be a great source of energy. The advantages it contains is greater compared to the other sources of energy. Tidal stream resource is extreme near the north eastern coast of Scotland. There are some issues throughout such as:

1) It is important to come up with calculated plans to help tackle and go after the TISEC industry evolution. The R&D is required to help with the development of this technology. This could be carried out between universities or private companies. The programs which could help demonstrate the performances and the benefits of these technologies could be pivotal.

2) There are many barriers to the development of TISEC. They can be related to permitting and different mechanisms. These barriers need to be dealt with. The mechanism which revolves around environmental tax called the carbon tax which is applied on CO_2 and the other greenhouse gases could be implemented.

3) The financing of the TISEC industry is in need to help ensure the evolution of the socioeconomic issues. They have to be coordinated carefully. The costs of the technologies related to tidal energy have to be reduced. There could be some incentives given to people investing such as tax credits. Or reduction in loans, etc. Also, in order to give people an assurance of the reduction of risk, subsidy payments should be given to the suppliers of electricity per unit of electricity which is produced.

4) The investors and people have to be made aware of the possibilities and benefits to buy these renewable projects.

5) The European framework regulations and the supply chain sectors have to be understood.

6) The benefits to the local communities have to be created in circumstances. Planning is a really important factor. The authorities need to be made aware of the tactical plans and strategies. They need to be dealt with swiftness.

The high costs related to the tidal energy is likely to hinder its evolution. On the other hand, its implementation can bring about several benefits. Scotland has substantial prospects of tidal renewable energy. Dundee and Nova Scotia have been able to depict a picture that has drawn attention. Taking into account the policies which have all bee set up. The challenge is for the engineers and the scientists to help with providing of the marine renewable energy targets. The politicians need to be supporting in removing the existing barriers and lead this to spectacular successes.

There are many uncertainties which will definitely require more investigations, experiences. Mostly the investigations have been positive. There are also issues with the grid connection. It is extremely difficult to find a site where both, the resource and the possibility of a grid connection exists. This technology depends a lot on the connection with the grid. With the high capital costs involved, it is likely to take some more time to develop completely. However, it is analysed that with the long-term benefits and upgrades, the limitations shall be overcome.

As discussed, and explored throughout the thesis, the issues related to the socioeconomic and the possibilities of evolution of TISEC are reaping benefits. These benefits influence several key industries, communities locally and regionally along with the jurisdictions.

Careful strategic planning and schemes need to be employed. These are what ensure the evolution of the TISEC industry in complete. The policies are extremely pivotal to help with the expanding of the tidal energy. Given how well these policies have been deployed and the strategic plans involved, they can help us reach into a green and sustainable future.

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